Regional Operational Plan ROP.SF.2A.2014.15

Susitna River Chinook and Coho Salmon Inriver Abundance and Distribution and Pink Salmon Spawning Distribution

by

Pete Cleary,

Johnathon Campbell,

and

Richard Yanusz

March 2015

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL OPERATIONAL PLAN ROP.SF.2A.2014.15

SUSITNA RIVER CHINOOK AND COHO SALMON INRIVER ABUNDANCE AND DISTRIBUTION AND PINK SALMON SPAWNING DISTRIBUTION

by

Pete Cleary

Johnathon Campbell

and

Richard Yanusz

Alaska Department of Fish and Game, Division of Sport Fish, Palmer

Alaska Department of Fish and Game

1800 Glenn Hwy., Ste. 2, Palmer AK 99645
Division of Sport Fish

March 2015

The Regional Operational Plan Series was established in 2012 to archive and provide public access to operational plans for fisheries projects of the Divisions of Commercial Fisheries and Sport Fish, as per joint-divisional Operational Planning Policy. Documents in this series are planning documents that may contain raw data, preliminary data analyses and results, and describe operational aspects of fisheries projects that may not actually be implemented. All documents in this series are subject to a technical review process and receive varying degrees of regional, divisional, and biometric approval, but do not generally receive editorial review. Results from the implementation of the operational plan described in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author if you have any questions regarding the information provided in this plan. Regional Operational Plans are available on the Internet at: http://www.adfg.alaska.gov/sf/publications/

Pete Cleary, Johnathon Campbell, and Richard Yanusz
Alaska Department of Fish and Game, Division of Sport Fish,
1800 Glenn Hwy., Ste. 2, Palmer, AK 99645

This document should be cited as:
Cleary, P., J. Campbell, and R. Yanusz. 2014. Susitna River Chinook and coho salmon inriver abundance and distribution and pink salmon spawning distribution. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.2A.2014.15 Anchorage.

SIGNATURE PAGE

Project Title:	Susitna River Chinook and coho salmon in-river abundance and distribution and pink salmon spawning distribution
Project leader(s):	Pete Cleary, Fishery Biologist II Johnathon Campbell, Fishery Biologist II Richard Yanusz, Fishery Biologist III
Division, Region, and Area	Sport Fish, Region II, Northern and Western Cook Inlet Area
Project Nomenclature:	
Period Covered	
Field Dates:	22 May, 2014 – 15 October, 2014
Plan Type:	Category III

Approval

Title	Name	Signature	Date
Project leader	Pete Cleary		5/21/14
Project leader	JOHNATHON CAMPBELL		21 May 2014
Project leader	Richard Yanusz		5/21/14
Biometrician	Dan Reed		5/22/2014
Research Coordinator	Timothy R McKinley		2/16/15
Regional Supervisor			

TABLE OF CONTENTS

Table of Contents (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The goals of this study are to estimate the abundance and distribution of Chinook and coho salmon and the spawning distribution of pink salmon in the Susitna and Yentna River drainages in 2014. A 2-event mark–recapture study will be conducted on the Susitna and Yentna rivers to estimate abundance, spawning distribution, and mortality rates. In the Susitna River, fish wheels and gillnets will be operated at river mile (RM) 34 to capture Chinook salmon for marking with radio tags. Second event sampling will occur at the Deshka River weir, Montana Creek weir, and Middle Fork Chulitna River. Coho salmon abundance will be estimated analogously, except gill nets will not be used to capture fish at the marking or tag recovery sites, and the Middle Fork Chulitna sonar will not be used for coho salmon recapture sampling. In the Yentna River, fish wheels and gillnets will be used at RM 7 to capture Chinook salmon for marking with dart tags. Second event sampling will occur at Yentna RM 18 using fish wheels and gillnets for the Chinook season and using fish wheels only for coho sampling.

Key words: chum salmon, coho salmon, abundance, mark–recapture, Susitna River, Yentna River, spawning distribution, fish wheel, radio telemetry

PURPOSE

The Alaska Energy Authority (AEA) has begun the planning process for the Susitna-Watana hydroelectric project (Su Hydro project), which would dam the Susitna River at project river mile (PRM)[1] 184 (http://www.susitna-watanahydro.org/; Figure 1). Salmon stock assessment and habitat utilization studies are part of the permit application process, and AEA awarded the Alaska Department of Fish and Game (ADF&G) funds for Chinook *Oncorhynchus tshawytscha*, coho *O. kisutch*, and pink salmon *O. gorbuscha* studies in the Susitna River. In addition, ADF&G has been allocated funds by the Alaska Legislature to estimate the escapement of coho salmon in the Yentna River in response to perceived low escapements.

In 2014, ADF&G plans to estimate the spawner distribution for Chinook salmon to both the Yentna and mainstem Susitna rivers, and estimate the spawner distribution for coho salmon in the mainstem Susitna River only. Inriver Chinook and coho salmon abundance estimates will be attempted for both the Yentna and mainstem Susitna rivers.

Data collected from these studies will supplement similar data collected in 2013. In 2013, Chinook salmon escapement into the mainstem Susitna River above the Yentna River was estimated to be 89,463 (SE = 9,523) using second event sampling data from Montana Creek and Deshka River weirs. Following the 2014 field season, a more refined and precise estimate for 2013 will be possible with the incorporation of second event sampling data collected at the Middle Fork Chulitna River sonar site. Data collected during 2014 will allow unbiased size stratification of observations collected at the sonar site. In 2013, insufficient data were collected during the experiment to estimate Chinook salmon escapement into the Yentna River due to unforeseen environmental conditions. In order to be successful at both locations in 2014, the same methods will be repeated for the mainstem Susitna River, but the Yentna study will be changed from a fish-wheel-to-weir/sonar mark–recapture design to a fish-wheel-to-fish-wheel mark–recapture design. In 2013, the escapement of coho salmon into the mainstem Susitna River was estimated to be 130,026 (SE = 24,342). Estimating coho salmon escapement into the Yentna

[1] Defined by AEA

River was not attempted in 2013. In 2014, the same methods will be repeated on the mainstem Susitna River, and a fish-wheel-to-fish-wheel mark–recapture design will be implemented on the Yentna River.

Additional data collected in 2014 will improve confidence in the spawning distribution and habitat use of each species and quantify the variation in that use. The 2014 abundance estimate for Chinook salmon in the entire Susitna River (mainstem Susitna plus Yentna rivers) will only be the second attempted since the 1984 estimate for the Su Hydro project, and comes at a time when unusually low abundance is causing widespread concern (ADF&G Chinook Salmon Research Team, 2013). In addition to the dam permit application, these data will be useful for interpreting present and past stock assessments, choosing future assessments that are efficient and effective, providing new knowledge to fishery managers and users, advising the Alaska Board of Fisheries regulatory process, and for land use planning and permitting.

OBJECTIVES

PRIMARY OBJECTIVES

1. Estimate the abundance of Chinook salmon greater than or equal to 500 mm mid eye to tail fork (METF) length in the mainstem Susitna River above the mouth of the Yentna River (PRM 34) such that the estimate is within 25% of the true value 90% of the time.
2. Estimate the abundance of Chinook salmon greater than or equal to 500 mm METF in the Yentna River above river mile (RM)[2] 7, such that the estimate is within 40% of the true value 90% of the time.
3. Estimate the abundance of coho salmon greater than or equal to 400 mm METF in the mainstem Susitna River above the mouth of the Yentna River (PRM 34) such that the estimate is within 40% of the true value 90% of the time.
4. Estimate the abundance of coho salmon greater than or equal to 400 mm METF in the Yentna River above RM 7, such that the estimate is within 40% of the true value 90% of the time.
5. Identify Chinook and coho salmon spawning locations in the mainstem Susitna River, by tagging site (fish wheel or gillnet), such that any spawning location used by at least 5% of the Chinook or coho salmon spawners captured in a particular fish wheel will be detected (≥1 radio tag) with probability of at least 99%, and determine if spawners are distributed uniformly among 20 locations where the probability of detecting all 20 locations is at least 99%. Any spawning location used by at least 5.0% of the pink salmon spawners captured in a particular fish wheel or Chinook salmon spawners captured with a gillnet will be detected (≥1 radio tag) with probability of at least 98%, and if spawners are distributed uniformly among 20 locations, the probability of detecting all 20 locations will be at least 69%.
6. Identify Chinook salmon spawning locations in the Yentna River, by tagging site (fish wheel or gillnet), so that any spawning location used by at least 5% of the Chinook salmon spawners captured with a gillnet or in a particular fish wheel will be detected (≥1 radio tag) with probability of at least 98%, and determine if spawners are distributed uniformly among 20 locations where the probability of detecting all 20 locations is at least 75%.

[2] Defined by the ADF&G Anadromous Waters Catalog

7. Estimate the proportions of Chinook and coho salmon inriver spawning abundances in 6 major tributaries (or groupings of minor tributaries) of the mainstem Susitna River, such that each proportion is within ±6 percentage points of the true value 90% of the time.
8. Estimate the proportions of Chinook salmon inriver spawning abundances in 7 major tributaries (or groupings of minor tributaries) of the Yentna River, such that each proportion is within ±7 percentage points of the true value 90% of the time.
9. Estimate the age composition of Chinook salmon passing the weir on Montana Creek, such that each age class is within ± 7 percentage points of the true values 95% of the time.

SECONDARY OBJECTIVES

1. Collect a tissue sample for genetic analysis from all salmon marked with a radio tag.
2. Collect a tissue sample for genetic analysis from 200 of the Chinook salmon sampled for scales at Montana Creek.
3. Estimate the mean length-at-age of Chinook salmon passing the Montana creek weir.
4. Radiotag 200 pink salmon in the mainstem Susitna River fish wheels to support companion AEA studies.

METHODS

FUNDAMENTAL DESIGN

There are no sites on the Susitna River below the confluence with the Yentna River (PRM 27) that make the entire salmon escapement available to sampling because the channel is braided with many small islands and sand bars, and the water velocity is too slow to concentrate fish in any particular channel. Instead, the Chinook, coho, and pink salmon escapements will be assessed independently in the mainstem Susitna and Yentna rivers (Figure 2).

Mainstem Susitna River

A 2-event, capture–recapture experiment will be used to estimate the inriver abundance of Chinook and coho salmon in the mainstem Susitna River. Fish wheels and gillnets will be used at PRM 34 to capture Chinook salmon for marking with radio tags, and fish will be examined for marks at recapture sites on the Deshka and Middle Fork Chulitna rivers and Montana Creek (Figure 2). The ability to operate weirs at the Deshka River and Montana Creek, and sonar at the Middle Fork Chulitna River, allows for very large sample sizes in the recapture events. By using radio tags as the mark, and automated radio receiver/loggers at the recapture sites, no fish will need to be handled at the recapture sites to find marked fish, speeding up the process and reducing stress on the fish. The radio tags will also be necessary to assess the spawning distribution, and so will serve 2 objectives. The coho salmon inriver abundance will be estimated in a nearly identical fashion, except gillnets will not be used to capture fish at the marking site, and that the Middle Fork Chulitna sonar will not be used for coho salmon recapture because chum and pink salmon return at about the same time as coho salmon, and sonar cannot differentiate the species.

Yentna River

A simultaneous, independent, 2-event, capture–recapture experiment will be used to estimate the inriver abundance of Chinook and coho salmon in the Yentna River. Fish wheels and gillnets will be used at RM 7 to capture Chinook salmon for marking with dart tags and a secondary mark, and the only recapture site will be fish wheels and gillnets at RM 18.8 (Figure 2). The Yentna River drainage does not have any clearwater tributaries with substantial Chinook salmon populations that have a suitable weir site, so the next best alternative for recapturing tagged fish is to sample fish further upstream in the mainstem Yentna River at RM 18.8 with the same methods. Since fewer fish will be examined for tags, more tags will need to be deployed, and dart tags are much cheaper than radio tags. Radio tags will also be deployed, in a subsample of Chinook salmon at RM 7 only, for assessing spawning distribution and quantifying the proportion of fish that drop out of the experiment. The coho salmon inriver abundance will be estimated in a nearly identical fashion, except that gillnets will not be used to capture fish at the marking site. Radio tags will be deployed on a small subsample of coho salmon only for quantifying the proportion of fish that drop out of the experiment.

For the spawning distribution in each drainage, all radiotagged salmon will be relocated using fixed tracking stations on major tributaries, stations located at weir and sonar sites, and repeated aerial surveys over the major tributaries (Figure 1).

SAMPLING METHODS

Marking Effort–Mainstem Susitna River

Chinook salmon tagging will occur from approximately 22 May to 30 June, 2014, and pink and coho salmon tagging will occur approximately 7 July to 20 August, 2014. Tagging will begin when water levels and debris loads allow for safe operations of fish wheels and gillnets.

At the mainstem Susitna River tagging site (Figure 3), fish wheels will be operated for 12 h per day each with 2-person crews (6 h/shift for 2 shifts; Appendix A1). Each fish wheel will be operated every day of the season, except for breakdowns, crew shortages, or unsafe weather.

Fish wheels will be aluminum, with three 6-ft wide baskets webbed with knotless, nylon, 1.5-in mesh netting (square measure). Captured fish will descend an aluminum basket chute to a fabric slide crossing above the float, and drop into the live box. Live boxes will be 8 ft long, 2 ft wide, and 4 ft deep, with plywood sides with holes cut to allow water circulation. The configuration of the fish wheel axle, baskets, and floats make the fishing depth a maximum of 6.5 ft. Fish wheels will be tied to the river bank and braced offshore with poles to position the wheels in sufficient current to make them spin. The axle height will be adjusted so that the baskets sweep as close to the river bottom as possible. A picket weir with 1.5-in gaps between pickets will be installed between shore and the fish wheel, to direct migrating salmon towards the fish wheel baskets.

In order to obtain a representative size sample of all migrating Chinook salmon, fish wheel samples will be supplemented by drift gillnets fished offshore of the fishwheels. In 2012 and 2013, Chinook salmon captured in gillnets had a larger mean length than those captured in fish wheels. Two drift net mesh sizes (5.5 in and 7.5 in, stretch measure) will be used. Nets will be 10–12 ft and 15–17 ft deep, respectively, for each mesh size. The desired capture technique will be to entangle fish by the snout to avoid injuries that gilling would cause.

A comparison of the length distributions of all Chinook salmon passing the Deshka weir and "recaptured" radiotagged fish past the weir indicated the 2012 sample of radiotagged fish was biased toward smaller fish, with the first point for stratification occurring at 580 mm METF. A comparison of the size distributions of all Chinook salmon captured with all gears at the mainstem tagging site and those past the Deshka weir indicates that fish less than 580 mm METF should be tagged at one-third the rate of larger fish to at least partially mitigate for size bias at the marking site. This differential tagging strategy was employed in 2013 and resulted in 15% of valid radio tags being deployed in Chinook salmon less than 580 mm METF. The proportions of Chinook salmon less than 580 mm METF estimated at the Chulitna River sonar site and at the Deshka River and Montana Creek weirs were 9.0%, 11.4%, and 10%, respectively. Had the differential tagging strategy not been used in 2013, approximately 35% of the radio tags would have been deployed in Chinook salmon less than 580 mm METF.

On the mainstem Susitna River, 700 Chinook salmon will be tagged with radio tags. The target distribution for radio tags will be 300 per fish wheel and 100 from drift gillnets. All captured Chinook salmon will be measured. Initially, all uninjured Chinook salmon greater than or equal to 580 mm METF will be tagged and every third (1/3) Chinook salmon greater than or equal to 500 mm METF and less than 580 mm METF will be tagged. A total of 600 coho salmon greater than or equal to 400 mm METF (300 per fish wheel) and a total of 200 pink salmon greater than or equal to 400 mm METF (100 per fish wheel) will be tagged with a radio tag.

Fish will be radiotagged at each fish wheel and via gillnet 7 d per week according to Tables 1–3. Tags will be deployed systematically, given that a fixed number of tags are to be deployed. Tagging healthy fish as soon as they are captured should avoid selection bias by the crews. Once the scheduled number of radio tags has been deployed for a particular fish wheel shift, the wheels will continue to be run for the duration of the shift and the number of fish caught recorded. However, once the scheduled number of radio tags has been deployed for a particular gillnet shift, netting will cease for that shift, to minimize stress on the rest of the fish population. The nets will be fished until corks sink, indicating a fish is in the net, and the fish will be immediately pulled in. One crew of 2 technicians will fish for up to 7.5 h per day, with start times rotating daily until a cycle is completed each week, to reduce bias due to the run timing of any individual stock (Table 1).

To minimize handling stress on all salmon, only Chinook salmon that have been held in the live box less than 1 h will be radiotagged. Radio telemetry data for coho salmon in the Kenai River indicated that fish tagged immediately upon capture experienced a mortality rate half that of fish that were held for variable times in the fish wheel live box before tagging (10% vs. 20% mortality, Carlon and Evans, 2007). Live box holding time for all radiotagged fish will be recorded. Preliminary results from identical holding time practices at Flathorn in 2010 showed minimal lingering tagging effects on most fish. After adjusting for tagging/handling loss (11% for chum, 12% for coho), upstream movement was detected in 91% of radiotagged chum salmon and 86% of radiotagged coho salmon within 1 day of release after tagging in 2010 (ADF&G, unpublished data).

Two-person crews will process selected salmon quickly to reduce handling time. Fish will be in a holding tank onboard a boat during tagging. A bucket will be used to frequently add water to the tank. A padded, aluminum cradle (Larson 1995) will be slipped around the fish to restrain it during tagging. One person will restrain the fish, the second will insert a radio tag, and record

data. Radio tags will be inserted through the esophagus and into the upper stomach using a 0.38-in outside diameter, 12-in long plastic tube. The antenna of the radio transmitter will be threaded through the tube and pinched by hand at the end of the tube, such that the radio transmitter is held tightly against the opposite end of the tube. Chinook salmon less than 500 mm METF will not be radiotagged because the large majority of such fish will likely be jacks. The size and weight of the radio tags used may have more impact on small fish, because the radio tag could be about 1.6% of the body weight of a 400-mm METF fish. Smaller radio tags will be used for pink salmon 400 to 420 mm METF (see Data Collection below). The plastic tube will be marked with reference points to assist in proper tag insertion depths. Resistance felt during tag insertion will be the most useful indicator, and the esophagus will be visually inspected to ensure none of the tag body is visible. The crew will measure METF and total length (TL) (Appendix B1), and remove and preserve the distal 0.5 cm of the left axillary process (Appendices B2–B3). TL is needed to perform length comparisons with fish at the sonar site.

Marking Effort–Yentna River

At the Yentna RM 7 site (Figure 3), Chinook salmon tagging will occur approximately 22 May to 30 June, 2014, and coho salmon tagging will occur approximately 7 July to 20 August, 2014. Tagging will begin when water levels and debris loads allow for safe operations of fish wheels and gillnets. Longer shifts at the RM 7 site are necessary to boost samples sizes. Two crews will work 9-h shifts each day to operate 2 fish wheels during daylight hours. Total effort for each fish wheel will be 16 h per day (8h/shift for two shifts; Appendix A2). Each fish wheel will be operated every day of the season, except for breakdowns, crew shortages, or unsafe weather.

The Yentna RM 7 fish wheels will be similar to the mainstem Susitna fish wheels, except for having 2 baskets, a wooden slide crossing above the float, live boxes 4-ft long, 4-ft wide, and 4-ft deep, and a maximum fishing depth of 4.5 ft.

Gillnet methods will be identical to those at the mainstem Susitna River site described above.

At the Yentna River tagging site, all healthy captured Chinook salmon greater than or equal to 500 mm METF and coho salmon greater than or equal to 400 mm METF will receive an individually-numbered, double-numbered, dart tag (model FT-1-94 from Floy® Tag, Seattle, WA) as the primary mark and a hole punch in the adipose fin as the secondary mark to assess tag loss. The same tag number will be printed twice on each dart tag, so that when a fish is recaptured, the distal tag number can be cut off for documentation of the tag number. The remaining portion of the dart tag in the fish will indicate the fish was previously sampled and thereby prevent double sampling. A total of 300 Chinook salmon greater than or equal to 500 mm METF will also be tagged with radio tags. The target distribution for radio tags will be 100 per fish wheel and drift gillnets. A total of 60 coho salmon (30 per fish wheel) greater than or equal to 400 mm METF will be tagged with a radio tag.

Chinook salmon will be radiotagged at each fish wheel and via gillnet 7 d per week according to Tables 1 and 4, and coho salmon according to Table 5. Tags will be deployed systematically, given that a fixed number of tags are to be deployed. Tagging healthy fish as soon as they are captured should avoid selection bias by the crews. Methods for deploying leftover tags, fish handling, and radiotagging methods will be identical to those at the mainstem Susitna River site described above. Once the scheduled number of radio tags has been deployed for a particular fish wheel shift, the wheels will still be run for the duration of the shift and to continue with dart tagging. Similarly, once the scheduled number of radio tags has been deployed for a particular

gillnet shift, netting will continue at Yentna RM 7 for the full duration of the shift, to maximize the number of dart tags deployed.

Spawning Location

For both the mainstem Susitna and Yentna rivers, movements of radiotagged fish will be monitored from time of release by a combination of aerial surveys and tracking stations at major tributaries and weir/sonar sites. Three tracking stations will be placed in the Yentna River drainage and 7 tracking stations upstream of Susitna PRM 34 (Table 6, Figure 1). All tracking stations will consist of at least 2 antennae, a receiver/logger, and self-contained power system. Radiotagged fish within reception range of the stations will be identified and recorded. Collected information will include the date and time the fish are present at the site, the signal strength and activity pattern of the transmitter (active or inactive), and the location of the fish in relation to the station (i.e., upriver or downriver from the site). Information on tracking station operations (i.e., voltage levels for the station components, and whether the reference transmitter at the site is being properly recorded) will also be collected. The 10 tracking stations will be located on important migratory corridors and below spawning grounds on major tributaries.

A fixed-wing aircraft will be used for aerial surveys. Two Yagi antennas, 1 on each side of the plane, will be mounted on a wing strut with the antenna oriented forward and slightly downward, and the elements vertical, to maximize the reception. Both antennae will be combined into 1 line to the receivers. An ATS™ R4520C radio receiver/logger with an internal global positioning system (GPS) receiver will be programmed to continuously scan all frequencies and create a log of the tags detected and the concurrent latitude and longitude.

Tracking flights will be made approximately every 2 weeks from 23 June through 30 September to locate radiotagged fish, weather permitting. The flights will cover major tributaries throughout the entire Susitna River drainage. Each transmitter will be located to approximately the nearest 1 km. Any transmitters signaling a mortality pulse will be noted. A handheld GPS, set to automatically record a track, will be operated for the full duration of each flight to document the extent of each survey.

For all salmon species, the radio transmitters will be manufactured by Advanced Telemetry Systems, Inc. (ATS™) and will operate on several frequencies within the 150.000–152.999 MHz range. Eighteen frequencies will have 100 pulse codes and 1 frequency will have 60, resulting in 1,860 uniquely identifiable transmitters. Each transmitter will be equipped with a mortality indicator mode that activates when the tag is motionless for approximately 24 h. All Chinook salmon will receive the ATS F1845B transmitters, which will be 52-mm long, 19 mm in diameter, have a mass of 26 g, have a 30-cm external whip antenna, and a nominal battery life of 311 d. This means the radio tags could operate until at least early March 2015, actual battery life will be determined once the options are programmed. Pink salmon less than 420 mm METF will receive the ATS F1835B transmitters, which will be 48-mm long, 17 mm in diameter, have a mass of 16 g, have a 30-cm external whip antenna, and a nominal battery life of 185 days. All other salmon will receive the ATS F1840B transmitters, which are 56-mm long, 17 mm in diameter, have a mass of 20 g, a 30-cm external whip antenna, and a battery life of 126 days.

Recapture Events–Mainstem Susitna River

Weir Operations

Floating weirs will be operated at the Deshka River and Montana Creek to count and sample Chinook and coho salmon. At each site, fixed radiotracking stations will be installed to record the radio frequency and pulse code of radiotagged Chinook and coho salmon as they migrate upstream. Daily counts of Chinook and coho salmon migrating through the weir will be recorded on forms and reported to the Palmer office. Radio receiver/loggers will be checked periodically to confirm their proper operation and to download data. Scales will be collected only from Chinook and coho salmon at the Deshka River weir because the genetic baseline for those stocks has already been documented. Scales and tissue samples will be collected from Chinook salmon, and only tissue samples from coho salmon, at the Montana Creek weir. A trap incorporated into the weir at each site will allow capture of fish for sampling. Other species counted through the weirs will be tallied.

Sonar Operations

A sonar will be operated on the middle fork of the Chulitna River to count migrating Chinook salmon. A partial rigid weir will be installed on the camp side of the river to force migrating Chinook salmon offshore and within the range of the sonar transducer. Data collected using the ARIS sonar unit will be summed daily and reported to the Palmer office, however final sonar counts will be generated post season. A fixed radiotracking station will be installed to record the date and radio frequency and pulse code of radiotagged Chinook salmon as they migrate past the sonar.

Fixed-location, side-looking sonar techniques are commonly used to obtain inseason estimates of run strength for anadromous fish stocks in rivers that are too wide for installing weir structures or too occluded for visual observations (Daum and Osborne 1998; Enzenhofer et al.1998; Gaudet et al. 1990; Maxwell and Gove 2007). In Alaska, sonar estimates of inriver passage often provide the basis for estimating spawning escapement and for regulating harvests of commercially important salmon stocks (Westerman and Willette 2006; Miller et al. 2010). Acoustic assessment sites currently exist on at least 10 rivers in Alaska. One of the barriers to wider use of sonar assessment has been the need to estimate the number of spawning salmon separately by species. Apportioning sonar counts by species often requires separate intensive sampling programs such as netting programs (Bromaghin 2005; Carroll and McIntosh 2008) or fish wheel programs (Fair et al. 2009) that are costly to implement and subject to biases that can be difficult to resolve.

No salmon other than Chinook salmon had been detected at the Middle Fork Chulitna sonar site in 2013, when sonar sampling was terminated on 29 July. Apportioning sonar counts by species during second event sampling at the Chulitna sonar site is unlikely to be necessary. However, if it is determined to be necessary, the apportionment process for these data will be relatively simple. Virtually all salmon greater than or equal to 700 mm METF passing any second event sampling site will be Chinook salmon, and the ratio of Chinook salmon 500–699 mm METF to those greater than or equal to 700 mm METF at the mainstem sampling sites in 2012 was fairly stable after the second week of sampling (P = 0.36 using contingency table analysis), though tending to decrease over the course of the run. Estimates of the length composition of salmon passing the sonar when the sonar is operating will be converted from sonar-measured lengths to METF and the relationship between Chinook salmon 500–699 mm METF to those greater than

or equal to 700 mm METF at that site will be used to estimate Chinook salmon passage if other species are present (see Data Analysis).

Adaptive Resolution Imaging Sonar (ARIS), the most recent DIDSON technology developed and manufactured by SMC will be used to detect fish. ARIS has several advantages over current DIDSON technology; it has user configurable window lengths (no longer restricted to discrete lengths) and improved downrange resolution (from 512 pixels to 4048 pixels). Additionally, ARIS is a "sealed" system, which should negate the need for using a "silt-excluding enclosure" to protect the system from silt buildup inside the lens cavity. The "silt socks" currently used to exclude silt have resolved the issue for the most part, but the "socks" are relatively fragile and can be breached easily if the system is subjected to impact with debris or the bottom during deployment and/or retrieval. These silt socks are not commercially available through the manufacturer but instead must be custom manufactured.

Fishwheel Operations (Optional)

For the mainstem Susitna River, an opportunity exists for additional second event sampling data to be collected by LGL, Inc. at fish wheels operated near Curry (PRM 120). All Chinook and coho salmon captured will be examined for the presence of a radio tag and length (METF) data will be collected. All Chinook and coho salmon examined at Curry that do not contain radio tags will be marked with a dart tag so that they can be uniquely identified if encountered at any weir sampling sites.

Recapture Events–Yentna River

Recapture event sampling data will be collected by fish wheels and gillnets operated in the Yentna River at RM 18.8, with nearly identical gear on the same schedule as at the Yentna RM 7 site. The only difference is that the fish wheels at RM 18.8 will be able to fish a maximum of 6.5 ft deep. All captured Chinook and coho salmon will be examined for the presence of a dart tag and a mark on the adipose fin. Fish with a whole dart tag that are recaptured will have half the tag (containing the tag number) cut off and will be measured for METF. All unmarked and marked Chinook salmon and a subsample of unmarked Chinook and coho salmon will be measured for METF each shift. Fish with half a tag will be ignored because the presence of a half tag indicates the fish was recaptured previously.

MARK–RECAPTURE:

Abundance–Assumptions and Testing

The 2-event closed population mark–recapture experiments are designed so that a Petersen-type estimator may be used to estimate abundance of Chinook and coho salmon. For these estimates of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures will be as follows:

Assumption I: The population is closed to births, deaths, immigration, and emigration.

Considering the life histories of these Chinook and coho salmon, there should be no recruitment between sampling events. First event sampling (marking) will begin prior to any significant passage of fish past the tagging sites and will continue through the run until passage has dropped to near zero. Some proportion of fish present at each of the mainstem Susitna River and Yentna River marking sites will not remain in the relevant experiment area. Also, some marked fish may fail to

enter and remain in the experiment areas due to handling stress. In the mainstem Susitna River experiments, radiotagged fish that do not spawn upstream of the tagging site or fail to enter and remain in the experiment area will be censored. In the Yentna River experiments, losses of fish due to either reason will be estimated from sample of marked fish that are also instrumented with radio tags.

Assumption II: There is no trap induced behavior.

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. We will attempt to meet this assumption by minimizing holding and handling time of all captured fish. Any obviously stressed or injured fish will not be tagged. Examples would be fresh seal bites that penetrate into the muscle, capture injuries such as torn opercula, large skin wounds or broken snouts, or being dropped in the boat while tagging.

Assumption III: Tagged fish will not lose their marks between sampling events and all marks are recognizable.

Tag loss will be estimated for the abundance experiments as described under Assumption I. Further, Chinook and coho salmon sampled at the Yentna River second event fishwheels will be examined for a marked adipose fin. A marked adipose fin with no dart tag will indicate the dart tag (primary mark) has been lost.

Assumption IV: One of the following three conditions will be met:

- All Chinook and coho salmon will have the same probability of being caught in the first event, or
- All Chinook and coho salmon will have the same probability of being captured in the second event, or
- Marked fish will mix completely with unmarked fish between samples.

In this experiment, it is unlikely that marked and unmarked fish will mix completely. Fish wheels will be operated continuously during the run, however probabilities of capture of both Chinook and coho salmon may change as their annual migration progresses. Fluctuations in water levels at first event sampling sites can affect the efficiency of fish wheels, resulting in variation in probability of capture over time. Also, the probabilities of capture will likely vary between fish wheel sites during the first event due to differences in channel morphology and water flow (Yanusz et al. 2007).

Use of weirs and sonar for second event sampling will not provide a simple random sample of all fish upstream of the tagging site. All salmon destined to spawn above our weir sites have a probability of being sampled approaching 1.0, while fish spawning elsewhere have a 0.0 probability of being sampled at a weir during the second event. While the second event sampling is not random, it will not necessarily provide a biased estimate of the marked:unmarked ratio. The diagnostic tests described below will identify appropriate remedial measures for departures from the conditions above and direction in selecting the most appropriate model(s) to estimate abundance.

Equal probability of capture will be evaluated by time, area, and size. The procedures to analyze length data for statistical bias due to gear selectivity are described in Appendix E1. If different probabilities are indicated, data will be fully stratified into size groups where probability of capture

is homogeneous within groups, and abundance estimates will be calculated for each size group and summed.

Contingency table analyses recommended by Seber (1982) and described in Appendix E2 will be used to detect significant temporal or geographic violations of assumptions of equal probability of capture. The test for complete mixing (Test I in Appendix E2) will not be performed. We expect the complete mixing condition will be violated geographically because a strong tendency for bank orientation by coho salmon at the Flathorn tagging site was demonstrated during the 2009 and 2010 radiotelemetry studies (Merizon et al. 2010, Cleary et al. 2013.) Examination of Chinook salmon data collected in 2012 suggested some bank orientation at the mainstem tagging sites by Chinook salmon spawning above the Deshka River weir, as a larger proportion of west bank captured fish entered the Deshka River than east bank captured fish (P = 0.21). The complete mixing condition cannot be satisfied temporally, due to experimental design and the time of movements of fish being investigated. If the test for equal probability of capture during the first event (Test II, Appendix E2) does not detect significant departure from this condition, this will likely be a result of the following: a) while variation in probability of capture occurred, it was not extreme, and b) some partial mixing does occur between sampling events to the extent necessary to buffer the effects of variation in probability of capture during the first event. Based on previous experience, it is anticipated geographic and possibly temporal violations of these assumptions will be detected, and a Petersen-type model would yield a biased estimate. Therefore, abundance will most likely be estimated using models developed by Darroch (1961) for a 2-event mark–recapture experiment on a closed population when temporal or spatial distributions of fish affect their probabilities of capture.

SAMPLE SIZES

Abundance–Mainstem Susitna River Chinook and Coho Salmon

Assessment of sampling effort necessary to achieve our precision criteria for Objectives 1 and 3 will be based largely on experience gained during the 2010–2013 experiments. We expect sampling rates (the proportions of the population passing each sampling site that are captured) will be similar in 2014 to what was experienced in previous years.

We determined the necessary sample sizes to meet the precision criteria in Objective 1 based on several assumptions about the outcome of our sampling efforts. This experiment is designed so that if all necessary experimental assumptions are met, an unstratified Petersen-type model could be used to estimate abundance of both Chinook and coho salmon. The approach of Robson and Regier (1964) was used to provide necessary sample sizes for a given population size and precision criteria. The interpretation of these sample size numbers was modified to accommodate mitigation for violations of necessary assumptions that we expect will be necessary for this experiment.

We expect that a Darroch (1961) model, rather than a Petersen-type model, will be necessary to estimate abundance of Chinook and coho salmon as a result of uncontrollable geographic and temporal variation in probability of capture during the experiment. In reviewing several salmon mark–recapture experiments where a Darroch-type model was required to estimate abundance, we observed that the unbiased CV for abundance estimates was 1.3 to 2.3 times as large as it might have been if necessary assumptions were satisfied and a Petersen-type model were appropriate. In 2010, the CV of our estimate of chum salmon abundance based on a Darroch model with correction for handling loss was approximately 1.6 times larger than would have

been realized using a Chapman estimator with no correction for handling loss for a similar size population size and sampling effort. Similarly, the CV of our coho salmon abundance estimate based on a Darroch model with correction for handling loss was approximately 2.0 times larger than provided by a Chapman model.

For these experiments, we assum that the CVs of our final estimates of abundance using the Darroch model, will be 2 times as large as we would see if no adjustments were necessary and a Petersen-type model were appropriate. The methods of Robson and Regier (1964) were used to calculate the necessary sample sizes, for different potential population sizes, to estimate abundances of Chinook salmon in the Susitna River drainage above the mouth of the Yentna River within 12.5% of the true values 90% of the time with a Petersen-type model. We expect that these same sample sizes will allow us to estimate abundances of Chinook salmon within 25% of the true values 90% of the time, after mitigating for violations of assumptions as described above. Based on results of the 2013 radiotagging experiment, we expect approximately 20% of the fish radiotagged at the mainstem wheels will be censored from the experiment because about 6% will not be detected at all or will only be detected downstream of the tagging site or will be harvested prior to spawning, plus up to 14% will spawn in the Yentna River system. Similarly for mainstem coho salmon, the methods of Robson and Regier (1964) were used to calculate the necessary sample sizes, for different potential population sizes, to estimate abundance within 20% of the true value 90% of the time with a Petersen-type model. We expect that these same sample sizes will allow us to estimate abundances of coho salmon within 40% of the true values 90% of the time, after mitigating for violations of assumptions as described above by using a Darroch (1961) model. Based on results of our 2013 experiment, we expect approximately 30% of the coho salmon radiotagged at the mainstem wheels will not be detected at all or will only be detected downstream of the tagging site or will be harvested before spawning.

The minimum sample size requirements and numbers of Chinook salmon expected to be sampled during first and second event sampling to estimate population sizes between 40,000 and 120,000 are presented in Appendix E3, Table E3-1. Using the 2012 radiotagging data and treating the Deshka River weirs as a second event sampling site, a (biased low) Petersen estimator suggests the number of Chinook salmon spawning above the mainstem tagging site was on the order of 40,000 to 80,000 fish ($\hat{N} \sim 58{,}000$). Also, approximately 33% of the deployed mainstem radio tags were detected above the Deshka River, Montana Creek, and Chulitna River weir sites or at the Curry fish wheels operated by LGL. In 2013, abundance of Chinook salmon in the mainstem Susitna River was estimated to be 89,463 with a 95% CI of (77,720, 114,954) with approximately 29% of spawning occurring above the second event sampling sites. For the mainstem Chinook salmon experiment, we need to inspect about 24% of the spawning population above the mainstem tagging site during second event sampling to achieve the precision criteria for Objective 5a (Appendix E3, Table E3-1), so our sampling design is expected to be adequate.

The minimum sample size requirements and numbers of coho salmon expected to be sampled during first and second event sampling to estimate population sizes from 40,000 to 120,000 are presented in Appendix E3, Table E3-2. The spawning distribution estimates from the 2010 coho salmon experiment (Cleary et al. 2013) suggest that about 9% of the coho salmon spawning in the mainstem spawned in the Deshka River and Montana Creek drainages. The preliminary 2012 results suggest approximately 12% of the mainstem spawners were in these 2 systems where

second event sampling for coho salmon will be conducted. In 2013, approximately 18% of the mainstem coho salmon spawned above the second event sampling sites. Abundance estimates from the 2010–2013 experiments suggest a population on the order of 80,000 to 130,000 coho salmon. We need to inspect about 15% of the spawning population above the mainstem tagging site during second event sampling to achieve the precision criteria for Objective 5a (Appendix E3, Table E3-1). Our sampling design will be adequate if spawning distribution is similar to what was estimated in 2013.

Abundance–Yentna Chinook and Coho Salmon

Based on sums of midrange Yentna River and mainstem Susitna River aerial survey escapement goals and expert opinion (Dave Rutz, personal communication), we expect that 34–40% of the spawning Chinook salmon in the Susitna River system upstream of Flathorn to spawn in the Yentna River, suggesting a spawning population on the order of 20,000 to 60,000 fish. Data from Yentna River Chinook salmon radiotagging in 2013 and passage at the Talachulitna River sonar site suggests an escapement into the Yentna River on the order of 50,000 to 60,000 Chinook salmon in 2013. Of the 694 Chinook salmon radiotagged at the Yentna River RM 7 fishwheels in 2013, 77 (11.1%) were not detected later, failed to enter the experiment area, or did not spawn upstream of the tagging site. Assuming a loss of marked fish of 15% and a 2014 Yentna River Chinook escapement of 60,000, we need to capture 2,150 salmon during both the first and second sampling events to achieve the precision criteria for Objective 2 (Appendix E3, Table E3-3).

Yentna River coho salmon abundance was estimated to be 122,777 (SE = 22,697) in 2010, 85,851 (SE =10,148) in 2011, and 93,932 (SE = 10630) in 2012, with catches at the lower Yentna River fishwheels (RM 7) of 6,134, 2,030, and 4,395 respectively. Assuming a loss of marked fish of 30% and an escapement of 120,000, we will need to capture 3,880 salmon during both the first and second sampling events. If the second event fishwheels at RM 18.8 can be fished as effectively as those at RM 7, sampling effort is expected to be sufficient to achieve the precision criteria for Objective 4 (Appendix E3, Table E3-4).

Spawning Location–Mainstem Susitna River Chinook, Coho, and Pink Salmon

For Chinook and coho salmon, the project will deploy 300 radio tags per fish wheel at PRM 34. We expect a 20% mark loss for Chinook salmon and a 30% mark loss for coho salmon. Using a Poisson model and assuming 20 spawning locations (aggregations of individual final radio tag locations), then any spawning location used by at least 5% of the spawners passing a fish wheel tagging site will be detected (≥1 radio tag) with probability of greater than 99%, and if spawners are distributed uniformly among 20 locations, the probability of detecting all 20 locations is greater than 99%.

A sample of 240 radio tags per fish wheel for Chinook salmon and 210 for coho salmon, applied proportional to run strength throughout the run, will be sufficient to meet the conditional precision criteria described in Objective 5. By deploying 300 tags per fish wheel, losses due to regurgitation or handling mortality of up to 20% for Chinook salmon and 30% for coho salmon will still allow the objective criteria to be met as long as tag loss is independent of spawning location. Independence will be assumed because it cannot be tested using this experimental design. If catches at any one fish wheel are so low or tag loss is so high that 240 tags cannot be tracked to spawning sites, the stated criteria will not be achieved for that fish wheel.

For Chinook salmon captured by gillnet and pink salmon captured in fish wheels, a sample of 80 radio tags, applied proportional to run strength throughout the run, will be sufficient to meet the conditional precision criteria described in Objective 5. By deploying 100 tags by gillnetting, losses due to regurgitation or handling mortality of up to 20% will still allow the objective criteria to be met as long as tag loss is independent of spawning location. Independence will be assumed because it cannot be tested using this experimental design. If gillnet catches are so low or tag loss is so high that 85 tags cannot be tracked to spawning sites, the stated criteria will not be achieved.

Spawning Location–Yentna Chinook Salmon

For Chinook salmon, the project will deploy 100 radio tags per fish wheel and gillnet site at RM 7. We expect a 15% mark loss for Chinook salmon. Using a Poisson model and assuming 20 spawning locations (aggregations of individual final radio tag locations), then any spawning location used by at least 5% of the spawners passing a fish wheel tagging site will be detected (≥1 radio tag) with a probability greater than 98%, and if spawners are distributed uniformly among 20 locations, the probability of detecting all 20 locations is greater than 75%.

For Chinook salmon captured by fish wheel and gillnet, a sample of 85 radio tags, applied proportional to run strength throughout the run will be sufficient to meet the conditional precision criteria described in Objective 6. By deploying 100 tags by gear type, losses due to regurgitation or handling mortality of up to 15% will still allow the objective criteria to be met as long as tag loss is independent of spawning location. Independence will be assumed because it cannot be tested using this experimental design. If gillnet catches are so low or tag loss is so high that 85 tags cannot be tracked to spawning sites, the stated criteria will not be achieved.

Spawning Distribution–Mainstem Susitna and Yentna rivers Chinook and Coho Salmon

Using the recapture data (radio tags in Chinook and coho salmon), variation in marked proportion among marking sites or over time can be tested, and an unbiased estimate of spawner distribution calculated if variation is not too severe. Prior to correcting for variation in probability of capture (assuming uniform probability of capture), the expected sample size of radiotagged Chinook salmon in the mainstem Susitna River experiment (560 assuming 20% tag loss) is greater than the 280 required to estimate the proportions of Chinook salmon traveling to different spawning locations such that each estimated proportion is within ±6 percentage points of the true values 90% of the time (Objective 7, Thompson 1987). For radiotagged coho salmon in the mainstem Susitna River, the expected sample size of 420 (assuming 30% tag loss) also exceeds the 280 required to estimate proportions of salmon traveling to different spawning locations.

Diagnostic tests for model selection for estimating abundance will provide evidence of potential geographic (between fish wheels) or temporal variation in probability of capture during the marking event, providing adequate direction for specifying a model or models for estimating abundance of fish passing the tagging sites by temporal and/or geographic strata based on probability of capture. Thus, groups of tags within strata can be properly weighed by estimates of the abundance of fish passing the tagging sites within strata. These weighted observations can be combined (see Data Analysis section) to provide unbiased or minimally biased estimates of the proportions of Chinook and coho salmon spawning in different tributaries.

Projecting the precision of estimates of proportions based on weighted tag observations, as described above, is very difficult. Empirical results from our 2013 mainstem Susitna River Chinook and coho salmon experiments provide an indication of the precision we might expect to see for estimates of spawning distribution for the 2014 Chinook and coho salmon experiments. For Chinook salmon in 2013, the value in the longer tail of a 90% confidence interval deviated from the point estimates by less than 5 percentage points in 6 out of 6 proportions estimated. For coho salmon, the deviation was less than 5 percentage points in only 3 out of 6 proportions estimated, and was less than 6 percentage points in 6 out of 6 estimates.

The expected sample size of radiotagged Chinook salmon in the Yentna River experiment (255, assuming 15% tag loss) is greater than the 205 required to estimate the proportions of Chinook salmon traveling to different spawning locations such that each estimated proportion is within ±7 percentage points of the true value 90% of the time (Objective 8, Thompson 1987). Because we have minimal empirical Chinook salmon data from the Yentna River, we simulated a Chinook salmon mark–recapture experiment that meets the precision criterion for Objective 2 with a population of 60,000 fish and with size-biased sampling using fish wheels and gillnets similar to that observed in the 2013 mainstem Susitna River experiment. The 2013 Yentna River radiotelemetry data were used to simulate the distribution of spawners by size strata. In the simulation results, the value in the longer tail of a 90% confidence interval deviated from the point estimates by less than 7 percentage points in 7 out of 7 proportions estimated. .

Size and Age Composition–Mainstem Susitna River Chinook Salmon

Assuming 25% of the Chinook salmon scales are unreadable at the Montana Creek weir site, a sample of 347 Chinook salmon will be required at each weir to achieve the precision criterion for Objective 9 (Thompson 1987). The planned sampling rate of 350 salmon will be adequate. Identical sampling criteria will be used for Deshka River Chinook salmon as part of another stock assessment project (Susie Hayes, ADF&G, Palmer).

Length composition data from these samples will be used to estimate the proportions of Chinook salmon less than or equal to 500 mm METF passing each weir site, and to estimate the size of the second event samples for the mark–recapture experiments. These data may also be used to estimate proportions of Chinook salmon in different size strata, should size stratification be required. A sample size of 354 would be required to estimate multinomial proportions within 6 percentage points of the true values 95% of the time—a level of precision sufficient to provide a small decrease in precision for the mark–recapture experiments given the other sources of uncertainty.

DATA COLLECTION

Each sampling site will provide a daily summary of catch, effort, and tagging, environmental conditions, and any operational changes to a biologist at the Palmer Division of Sport Fish office via telephone 5 d per week. Division of Commercial Fisheries–Soldotna will operate the Yentna RM 7 site. Yentna RM 7 crews will maintain daily contact with the Soldotna ADF&G office for camp logistical needs, and will contact the Palmer office directly to relay their daily summaries.

Abundance

Marking Event–Both Sites

At each site, fish wheel tag deployment or recovery data will be recorded in an Excel data sheet on a Dell Venue 8 Pro Tablet and downloaded after each shift to a camp laptop computer via the tablet SD card. For consistency, the Excel data sheet will be identical for each site. Fish wheel catch and effort data will be recorded on the 2014 Catch and Effort data form. The form will be filled with the following: date, crew initials, total fish wheel operation time, shift, start and stop times, crew arrival and departure times, and the total number of Chinook, coho, and pink salmon tagged and untagged (Appendices C1–C2). In addition, the total number of other species captured during the shift will be recorded.

Marking Event–Mainstem Susitna River

During Chinook salmon tagging, a total of 6 people will be used: 2 crews of 2 people to run the fish wheels for 2 shifts each day, and 1 crew of 2 people to sample with drift gillnets, in a split shift. The number of radio tags deployed each day for Chinook, pink, and coho salmon will occur according to a daily schedule (Tables 1–3). Each fish wheel will be operated in two shifts for a total of 12 h each day. Sampling effort will begin when the live box door is installed to hold captured fish, approximately 1 h after the crew starts its shift, allowing for sampling preparation and travel time. The first shift will begin at 0500 hours and will end at 1300 daily, and the second shift will be from 1400 to 2200 daily (Appendix A1). After a shift with 6 h of effort, the live box door will be pulled so that captured fish can escape. The crew will spend the remainder of its shift performing data compilation and equipment maintenance. The fish wheel will be allowed to run, in order to prevent debris from building up on the submerged basket.

The radio tags will be evenly split between the first and second shifts, with odd numbers of tags alternating between the shifts. If the scheduled number of radio tags for a given species cannot be deployed at a given wheel due to low catch during that shift, the leftover tags will be deployed by the next shift, even if it is the following day. The next shift will deploy its regularly scheduled tags first, then the leftover tags. This will continue until the leftover tags are deployed, and the crew can get back on the original schedule. So that radio tags are deployed in proportion to the run, the number of tags deployed from each wheel may be adjusted depending on catch rates. Actual deployment of tags will be recorded in Tag Deployment and Tag Deviation Logs (Appendices B4 and B5).

Pink salmon 400–420 mm METF will be radiotagged with a model F1835B radio tag (small). Pink salmon greater than 420 mm METF will be radiotagged with a model F1840B radio tag (regular size). Equal numbers of pink salmon will be tagged with the two sizes of tag. In order to minimize fish wheel injuries, closed-cell foam padding will be placed where appropriate to prevent injuries as fish exit fish wheel basket chutes. In 2012 and 2013, padding was placed along the edges of the live box and on the edges of the live box slide.

Fish wheel operations

1. Each fish wheel will be visited every 1 hr or less. When a fish wheel has been untended for more than 1 hr, all the fish in the live box shall be counted, measured if due, and released, but not radiotagged.
2. Fish that are bleeding will measured and released.
3. No tagging will occur without first placing the fish in water.

4. The first *n* (where *n* = the number of radio tags to be deployed for the shift/species) healthy (without recent injuries and not having fallen in the boat) Chinook salmon greater than or equal to 580 mm METF will be tagged and every third (1/3) Chinook salmon greater than or equal to 500 mm METF and greater than 580 mm METF will be tagged. The actual number of tags deployed will be compared to the scheduled number to be deployed every 5 d (Table 2), on 29 May, and 3,8, 13, and 18 June, in order to adjust the tagging rates if tags are being deployed too quickly. If tags at a particular fish wheel are being deployed too slowly (i.e., the tag surplus keeps building), the surplus may be reassigned to another fish wheel or to the gillnets in order to utilize all tags by 30 June.
5. The first *n* healthy coho salmon greater than or equal to 400 mm METF caught each shift will be placed in a water-filled tote with a cradle and tagged with a radio transmitter.
6. The first *n* healthy pink salmon 400–420 mm METF will be radiotagged with a model F1835B radio tag (small), and *n* healthy pink salmon greater than 420 mm METF caught each shift will be radiotagged with a model F1840B radio tag (regular size).
7. For every radiotagged fish, the distal 0.5 in of the left axillary process will be removed and preserved in a uniquely-numbered vial with ethanol (Appendices B2–B3).
8. All Chinook salmon (both radiotagged and not tagged) will be measured for METFlength and TL, and only radiotagged coho and pink salmon will be measured for only METF length (Appendix B1).
9. Untagged coho and pink salmon will be tallied and released.
10. Once the radio tags for a shift have been deployed, the fish wheel will continue to be operated until the end of the shift.
11. Other fish species will be tallied on the data form and the fish released.
12. If the *n* radio tags scheduled for a shift cannot be deployed to low catches, those tags shall be deployed on the next shift(s).

For Chinook salmon at the beginning of the season, *n* will follow Tables 1 and 2. If tags at a particular fish wheel are being deployed too slowly (i.e., the tag surplus keeps building), the surplus may be reassigned to another fish wheel or to the gillnets in order to utilize all tags by 30 June. Tags will not be shared between the mainstem Susitna and Yentna rivers. For coho salmon at the beginning of the season, *n* will follow Table 3. If tags at a particular fish wheel fall behind schedule (i.e., the surplus tags keep building), the surplus may be reassigned to the other fish wheel in order to utilize all tags by 20 August. For pink salmon, to start the season, *n* will follow Table 3. If tags at a particular fish wheel fall behind schedule (i.e., the surplus tags keep building), the surplus may be reassigned to the other fish wheel in order to utilize all tags by 16 August.

Drift net operations

Drift gillnetting will take place midchannel, if possible, and between the fish wheel sites to sample Chinook salmon not susceptible to fish wheel capture. Prior to using new drift nets, old nets will be used to practice drift fishing and locate fishing sites that do not have snags. Drift net mesh sizes (5.5 in and 7.5 in, stretch measure) will be used. Nets will be 10–12 feet and 15–17 feet deep for each mesh size, respectively. Drift locations, duration, and net depth will be changed accordingly to depth or when net snags are found at fishing sites. One mesh size will be used per split shift, and each split shift will use a different mesh size, so that each mesh size gets approximately an equal amount of effort each day. Two technicians will make as many drifts as possible during each split shift, to achieve a total of 6 h per day of fishing effort for both shifts

combined. After the *n* radio tags are deployed for each shift, drift net operations will cease. During the early part of the season, most of a shift will be spent fishing. However, when catches increase, radio tags will be deployed in the beginning of the shift. After radio tags are deployed for each shift, crews will be assigned other tasks to complete their shift.

The desired capture technique will be to entangle fish by the snout to avoid injuries that gilling may cause. The net will be watched continuously until corks sink, then the net will be pulled in immediately.

Salmon captured in drift nets and will be processed as follows:

1. Captured Chinook salmon will be immediately removed from the net and placed in a tote with water.
2. The first *n* (where *n* = the number of radio tags to be deployed for the shift/species) healthy Chinook salmon greater than 500 mm METF caught each shift will be placed in a cradle in a water-filled tote, and tagged with a radio transmitter.
3. Radio tagging will occur according to a tagging rate, initially set at every uninjured Chinook salmon greater than or equal to 580 mm METF and every third (1/3) Chinook salmon greater than or equal to 500 mm METF and less than 580 mm METF.
4. The distal 0.5 cm of the left axillary process will be excised and preserved from every radiotagged Chinook salmon for later genetic assay.
5. All other captured Chinook salmon (injured/released) will be measured for METFlength and TL.
6. If the *n* radio tags scheduled for a shift cannot be deployed to low catches, those tags shall be deployed on the next shift(s).
7. Other fish species will be tallied on the data form and the fish released.

Marking Event–Yentna Site

At the Yentna River site, 6 individuals will make up 2 crews of 2 to run the fish wheels for 2 shifts each day, and 1 crew of 2 to sample with drift gillnets. At the Yentna tagging site each fish wheel will be operated for a total of 16 hr each day, in two 18-hr shifts. Sampling effort will begin when the live box door is installed to hold captured fish, approximately 1 h after the crew starts its shift, allowing for sampling preparation and travel time. The first shift will begin at 0300 hours and will end at 1200 (Appendix A2). The second shift will start at 1300 and end at 2200.

The radio tags will be evenly split between the first and second shifts, with odd numbers of tags alternating between the shifts. If the scheduled number of radio tags for a given species cannot be deployed at a given wheel due to low catch during that shift, the leftover tags will be deployed by the next shift, even if it is the following day. The next shift will deploy its regularly scheduled tags first, then the leftover tags. This will continue until the leftover tags are deployed, and the crew can get back on the original schedule. So that radio tags are deployed in proportion to the run, the number of tags deployed from each wheel may be adjusted depending on catch rates. Actual deployment of tags will be recorded in Tag Deployment and Tag Deviation Logs (Appendices B4 and B5).

Fish wheel operations

1. Each fish wheel will be visited every 1 hr or less. When a fish wheel has been untended for greater than 1 hr, all Chinook and coho salmon in the live box shall be counted, measured, and released, *but not tagged*.
2. Fish that are bleeding will measured and released.
3. No tagging will occur without first placing the fish in water.
4. The first *n* (where *n* = the number of radio tags to be deployed for the shift/species) healthy (without fresh/recent injuries and not having fallen in the boat) Chinook salmon greater than 500 mm METF and coho salmon greater than 400 mm METF caught during each shift will be placed in a water-filled tote with a cradle and tagged with a radio transmitter in addition to a dart tag and an adipose fin punch.
5. For every radiotagged fish, the distal 0.5 in of the left axillary process will be removed and preserved in a uniquely-numbered vial with ethanol.
6. If the *n* radio tags scheduled for a shift cannot be deployed due to low catches, those tags shall be deployed on the next shift(s).
7. All other healthy Chinook salmon greater than 500 mm METF and coho salmon greater than 400 mm METF will be placed in a water-filled tote with a cradle and will be tagged will with an individually numbered dart tag and also receive an adipose fin punch as a secondary mark.
8. All Chinook and coho salmon will be measured for METF.
9. Other fish species will be tallied on the data form and released.

For Chinook salmon at the beginning of the season, *n* will follow Table 4 at the Yentna River site. If tags at a particular fish wheel are being deployed too slowly (i.e., the tag surplus keeps building), the surplus may be reassigned to another fish wheel or to the gillnets in order to utilize all tags by 30 June. Tags will not be shared between the mainstem Susitna and Yentna rivers. For coho salmon, to start the season, *n* will follow Table 5 at the Yenta River site. If tags at a particular fish wheel fall behind schedule (i.e., the surplus tags keep building), the surplus may be reassigned to the other fish wheel in order to utilize all tags by 20 August.

Drift net operations

Drift gillnetting will take place midchannel, if possible and between the fish wheel sites to sample Chinook salmon not susceptible to fish wheel capture. Prior to using new drift nets, old nets will be used to practice drift fishing and locate fishing sites that do not have snags. Drift net mesh sizes (5.5 in and 7.5 in, stretch measure) will be used. Nets will be 10–12 feet and 15–17 feet deep for each mesh size, respectively. Drift locations, duration, and net depth will be changed accordingly to depth or when net snags are found at fishing sites. One mesh size will be used per split shift, and each split shift will use a different mesh size, so that each mesh size gets approximately an equal amount of effort each day. Two technicians will make as many drifts as possible during each split shift. Gillnets will be fished continuously at the Yentna deployment site to achieve 8 h per day of fishing effort, to maximize the dart tag deployment and to deploy radio tags as scheduled.

The desired capture technique will be to entangle fish by the snout, to avoid injuries that gilling may cause. The net will be watched continuously until corks sink, then the net will be pulled in immediately.

Salmon captured in drift nets and will be processed as follows:

1. Captured Chinook salmon will be immediately removed from the net and placed in a tote with water.
2. The first *n* (where *n* = the number of radio tags to be deployed for the shift/species) healthy Chinook salmon greater than 500 mm METF caught during each shift will be placed in a cradle in a water-filled tote, and tagged with a radio transmitter and dart tag and an adipose fin punch.
3. The distal 0.5 cm of the left axillary process will be excised and preserved from every radiotagged Chinook salmon for later genetic assay.
4. To start the season, *n* will follow Table 4 for radiotag deployment..
5. If the *n* radio tags scheduled for a shift cannot be deployed due to low catches, those tags shall be deployed on the next shift(s).
6. All other healthy Chinook salmon greater than 500 mm METF will be placed in a water-filled tote with a cradle and will be tagged will with an individually numbered dart tag and also marked with an adipose fin punch.
7. All other captured Chinook salmon (injured) will be measured for METF length.
8. Other fish species will be tallied on the data form and the fish released.

Recapture Events–Mainstem Susitna River Sites

Weir Sites

The crew at the Montana Creek weir will record the following data on a 2014 weir daily reporting form (Appendix B2): day, date, total count, other species, and crew member initials. Tasks will be as follows:

1. Count and record all salmon, by species, through the weir.
2. For Chinook salmon, measure 350 fish for METF length and TL (to the nearest 5 mm) and collect three scales from the same fish (Appendix D1). Every fifth Chinook salmon will be sampled, based on the 2013 weir count of 2,000 Chinook salmon at Montana Creek (2,015/350, rounded down to be conservative), and assuming a similar, low run size.
3. For coho salmon, 200 fish will be measured for METF length and TL (to the nearest 5 mm). Up to forty coho salmon will be sampled per week.
4. Optional—note dart tagged fish, record dart tag information if convenient.
5. At request—ensure fixed radio stations have power and are scanning.
6. Record water level and temperature, and cloud cover.

Sampling at the Deshka River weir is being conducted by an independent project, and will follow similar methods in a separate operational plan (Hayes, ADFG Palmer, personal communication).

Sonar operations

Sonar Deployment

At the Middle Fork Chulitna River, sampling will be controlled by electronics housed in a plastic fish tote located on the bank of the river. The ARIS will be mounted on remote pan and tilt systems (a Remote Ocean Systems PT-25 pan and tilt unit on the right bank and a Sound Metrics Corporation (SMC) X2 on the left bank) for precise aiming in the horizontal and vertical axes. The combined sonar and rotators will be deployed in the river on a tripod-style mount. In the

horizontal plane, the sonar will be aimed perpendicular to the flow of the river current to maximize the probability of insonifying migrating salmon from a lateral aspect. Internal attitude sensors in the ARIS will provide measurements of compass heading, pitch, and roll. An AIM 2000 attitude sensor attached to the bank mount will provide depth measurements throughout the season.

Communication cables feed directly into the right bank Top Side Box and data collection computer.

Sampling Procedures

A rigid weir will be installed on each bank to force salmon through the insonified zone. The ARIS will be positioned to record all images of salmon passing the gap between the rigid weir panel. Images will be recorded 24 hours per day, 7 days per week. When counts are missing, the missing values will be treated as though they occurred randomly and the existing data will be expanded accordingly.

Data Acquisition

The transmit power of the sonar is fixed and the maximum receiver gain (−40 dB) will be used during all data collection. The lens focuses to the midrange of the gap between the weir panels.

Data Storage

One laptop will be dedicated to collecting data. To ensure correct time stamps in the filenames, the laptop clock will be synchronized using GlobalSat BU-353 Waterproof USB GPS receivers. Initially, data will be collected by the host computer hard drive and subsequently transferred to two 1-TB external hard drives (2 redundant copies) for permanent archiving at the site. Data transfer to the Palmer office will occur using 1-TB portable hard drives. In the Palmer office data will then be transferred to an 8-TB RAID where it can be shared with up to 7 users through a 1-GB Ethernet network (i.e., through an 8-port, 1-GB Ethernet switch and 1-GB Ethernet cards in each computer).

Manual ARIS-based Fish Length Measurements

Estimates of TL will be made from images using the manual fish-measuring feature also included with the SMC ARIS Control and Display software. Collaborative efforts with SMC have resulted in a reasonably efficient method of manually measuring individual fish. During the 2014 season, efforts will be made to manually measure all fish with lengths exceeding approximately 400 mm TL. Detailed instructions for taking manual measurements and the software settings and parameters used are given in Appendix F1.

Seining at Sonar Site

Seining will be conducted once per week to detect upstream passage of salmon species other than Chinook starting 1 July 2014. For each day seining, 4 seine hauls will be completed. The seining will occur at the closest logistically feasible site in the vicinity of the sonar site. ASL data and genetic samples will be collected from Chinook salmon, while other species will be enumerated. In 2014, seining locations will be identified upstream of the sonar site. Initially, sites will be located using a Robinson R44 helicopter during resupply trips and then revisited for sampling when appropriate. Hook and line will also be used opportunistically.

Recapture Event–Yentna Site

Chinook and coho salmon will be sampled for marks at Yentna RM 18.8 using fish wheel and drift gillnet effort and schedules nearly identical to those used at Yentna RM 7. Drift gillnetting will cease approximately 7 July, and only fish wheel effort will continue until approximately 30 August. All Chinook and coho salmon will be examined for an adipose fin punch to detect dart tag loss. All Chinook salmon and the first 3 coho salmon without tags captured each shift on each wheel, every day, will be measured for METF length (i.e., 3 coho salmon × 2 wheels × 2 shifts = 12 total unmarked coho salmon per day). Every tagged fish recaptured will be measured for METF length and the dart tag number recorded. The distal half of the dart tag will be cut off and saved in a plastic bag as documentation of the tag number.

GENETICS SAMPLES

At both the mainstem Susitna River and Yentna River marking sites, the tissue samples from each radiotagged Chinook, coho, and pink salmon will be placed in a uniquely-numbered (radio tag number) vial and preserved in ethyl alcohol. The radio tag number will be used to link the spawning location and genetic data for individual salmon (Appendix A3). These samples will be archived for use in possible future genetics studies. All salmon samples and relevant collection data will be shipped to the ADF&G-CF Gene Conservation Lab in Anchorage at the end of the season.

SPAWNING LOCATION

Radio receivers (ATS™ Model R4500C) at each stationary tracking site will be visited and data will be downloaded twice a month. Each record will contain the following fields in ASCII text format: year, Julian day, hour, minute, antenna, frequency, pulse code, signal strength, and duplicate counts. A laptop computer will be connected to the radio receiver with a serial cable and ATS software will be used to transfer the data file to the laptop. A logbook will be maintained at each station to note the date, staff, settings, and battery voltage for each visit. A checklist with radio receiver settings and the download steps will be at each site. Each downloaded file will be transferred to the Palmer local area network (LAN) and eventually appended into a single file.

Each record in the file will contain the site code, download date and time, radio frequency and pulse code, date and time of detection, antenna number, period, and signal strength (ATS™ unpublished). Each daily file will eventually be appended into a single file.

Aerial telemetry surveys will be conducted on the Susitna mainstem and Yentna rivers as well as the primary tributaries, to verify data collected at tracking stations and identify the locations of radiotagged fish during the likely spawning period. Spawning sites will be inferred by maximum upstream locations of radio tags. Automatically recorded data will include the date and time of decoding, and the frequency, pulse code, latitude and longitude, signal strength, and activity status of each decoded transmitter. Decisions to continue or terminate any given survey will be made real time as the number of tags found becomes apparent.

When the radio receiver operator hears a tag, the "HOLD" button will be pressed, and the receiver will lock on the frequency to identify the pulse code. When the "HOLD" button is pressed, the frequency, pulse code, mortality indicator, signal strength, and latitude-longitude will be automatically written to the internal memory of the receiver. The data in the internal

memory will be downloaded to a Windows (Microsoft) based personal computer after each survey daily. The flight path will be automatically recorded on a handheld GPS (Garmin Oregon) and then downloaded, using Minnesota Department of Natural Resources DNRGPS software, to a Windows (Microsoft) based personal computer after each survey to document the drainages surveyed.

DATA REDUCTION

Data collected by SF and CF crews will be entered into Excel spreadsheets and stored in a dedicated subdirectory on the Palmer ADF&G LAN inseason as they become available and also uploaded to Docushare at the ADF&G Region II office (http://docushare.sf.adfg.state.ak.us/dsweb/HomePage). Individual files will be imported into an SQL database.

Raw data files downloaded from ATS radio receiver/loggers and GPS instruments will be treated as above. Dart tag recovery data from the recapture sites will be entered by hand into a separate Excel worksheet and stored and imported into the SQL database as above.

Raw data will be imported into an SQL Server telemetry project database that contains all aerial and station telemetry and fish tag data from 2006 through present. Database reports will be generated throughout the season in order to track progress. Queries for standard data analysis (i.e., tables and figures for reports) will be available to project personnel for data retrieval. Custom queries will be written upon request for dissemination of data to biologists and biometricians.

The database will serve as the basis for all data analysis required to achieve the study objectives. After all data are edited and analyzed, a final copy of the database (in comma delimited ASCII format) will be e-mailed, along with a data map, to Research and Technical Services (RTS) in the Anchorage ADF&G office for archiving on the SF intranet site.

DATA ANALYSIS

ABUNDANCE

A 2-sample mark–recapture model will be used to estimate the number of Chinook and coho salmon passing by the first event sampling sites. The appropriate abundance estimator will depend on the results of the aforementioned tests. If stratification is not needed, Chapman's (1951) version of Petersen's abundance estimator for closed populations (see Seber 1982) will be used:

$$\hat{N} = \frac{(M+1)(\hat{C}+1)}{(R+1)} - 1 \qquad (1)$$

where $\hat{N}$ = estimated number Chinook or coho salmon, M = the number of marked Chinook or coho salmon moving upstream of the Susitna mainstem or Yentna rivers wheel tagging sites, $\hat{C}$ = the estimated number of Chinook salmon greater than or equal to 500 mm METF or the number of coho salmon greater than or equal to 400 mm inspected for marks at the second event sampling sites, and R = number of marked Chinook or coho salmon recaptured during second event sampling. For Chinook salmon, we will estimate

$$\hat{C} = \sum_{i=1}^{s} C_i \hat{p}_{500+,i} \tag{2}$$

where C_i = total number of Chinook salmon counted past second event sampling site i (i = 1 to s where s = 2 for the Yentna experiment and s = 4 for the mainstem experiment), $\hat{p}_{500+,i}$ = estimated proportion of Chinook salmon at site i that were greater than or equal to 500 mm METF. Length composition data collected at each 2nd event sampling site will be used to estimate:

$$\hat{p}_{500+,i} = n_{500+,i} / n_i \tag{3}$$

where n_i = total number of Chinook salmon sampled at site i, and $n_{500+,i}$ = those members of n_i that were greater than or equal to 500 mm METF.

If temporal/geographic stratification is not required but stratification by size or sex is (see Appendix E1), the data will be fully stratified and estimates for each stratum will be generated using Equations 1–3. These stratum estimates will be summed to estimate total abundance and variance.

An estimate of the variance for $\hat{N}$ will be obtained through bootstrapping (Efron and Tibshirani 1993), however deviating from the methods in Buckland and Garthwaite (1991) because second event sampling is not random. The number of recaptures R will be modeled as a binomial proportion of the number of marks deployed M and a large number of bootstrap samples R^* will be generated. At each second event sampling site, the proportions of Chinook salmon greater than or equal to 500 mm METF will be modeled as a binomial processes as described in Equation 3, a large number of bootstrap samples will be generated for each $\hat{p}_{500+,i}$ and bootstrap samples of $\hat{C}^*$ will be calculated using Equation 2. Subsequently, bootstrap sample $\hat{N}^*$ will be calculated using Equation 1.

A minimum of 1,000,000 bootstrap samples (B) will be so drawn. The approximate variance will be calculated as follows:

$$\mathrm{var}(\hat{N}) = \frac{\sum_{b=1}^{B} (\hat{N}_b^* - \bar{\hat{N}}^*)^2}{B-1} \tag{4}$$

where $\bar{\hat{N}}^*$ is the average of the $\hat{N}_b^*$.

Where sonar operations are used for second event sampling, C_i as described in Equation 2 above will be estimated for the sampling conducted with sonar. These procedures are described below. Uncertainty resulting from these estimation procedures will also be modeled using bootstrap procedures, integrated into the processes described above.

If geographic or temporal stratification is required, estimation of abundance will follow procedures described by Darroch (1961). Initial modeling will be conducted using the computer program SPAS (Arnason et al. 1996). If stratification by size is required, size stratification will be conducted first and methods to correct for geographic or temporal capture heterogeneity will be applied independently to each size stratum. The contingency tables described in Appendix E2 will be further analyzed to identify a) First event strata (individual or contiguous groupings of

temporal/geographic categories) where probability of recapture during the second event is homogeneous within strata and different between strata, and b) second event strata where marked:unmarked ratios are homogeneous within strata and different between strata. Temporal categories generally will consist of groupings of sample data collected by week. Stratification will also be guided by environmental conditions encountered during data collection (river stage height and rainfall) and by previous experience gained when conducting mark–recapture experiments on this system. If the initial stratification does not result in an admissible maximum-likelihood (ML) estimate of abundance, further stratification may be necessary before an admissible estimate can be calculated. Nonadmissible estimates include failure of convergence of the ML algorithm in SPAS or convergence to estimators with estimated negative capture probabilities or estimated negative abundance within stratum. Goals in this case are always that observations within the pooled strata should be as homogeneous as possible with respect to capture, migration, and recapture (Arnason et al. 1996).

A Goodness of Fit (GOF) test (provided in SPAS) comparing the observed and predicted statistics will indicate the adequacy of a stratified model. GOF will be evaluated once the stratification that results in an admissible estimate of abundance is identified. Further stratification, according to the guidelines described above, may be necessary to produce a model and abundance estimate with a satisfactory GOF. In general, the model selected will be that which provides an admissible estimate of abundance where no stratification guidelines are violated, no significant evidence of lack of fit is detected, and the smallest number of strata parameters are estimated for the model. This model will usually yield the smallest ML estimate of variance for the abundance estimate.

If the Darroch (1961) procedure is used to estimate abundance and the number of first event (s) and second event (t) strata in the preferred model is not equal, further modeling will be conducted to identify an alternative preferred model with s equal to t. The reason for the alternative model is that an analytical solution may be calculated for the ML estimate of abundance using equations provided in Seber (1982)—no ML search algorithm is required. An analytical solution greatly simplifies the bootstrap modeling that will be used to estimated variance (described below). For $s < t$, typically the largest (most recaptures) marking strata in the preferred model can be divided into 2 or more smaller strata to increase s. For $s < t$, the second event strata will be divided to provide a larger t. Several alternative models, constructed in this manner, may be explored using the SPAS software. For all but the most ill-behaved data sets, this process will commonly produce one or more alternative models where $s = t$ and the ML estimates of abundance and SE are nearly identical to, and not statistically discernable from, those estimates from the preferred model. The chosen alternative model will be that for which the parameter estimates most closely match the preferred model.

The SPAS software will provide an underestimate of the true variance because the estimated components of $\hat{M}_{c,\bullet}$ will be treated as scalars, rather than random variables. Using the preferred alternative model ($s = t$), bootstrap methodology (Efron and Tibshirani 1993) will be used to estimate variance and confidence intervals. The procedures describe in Equations 2–4 will generally be followed, except a more complex *epd* for fish in the population will be required. There will be (s) (t) capture histories for recaptured Chinook or coho salmon, s capture histories for salmon marked but never recaptured, t histories for coho salmon captured upstream in the inriver fisheries without marks, and 1 history for all salmon never caught.

Similar to what was described above for the Chapman estimator, a minimum of 1,000,000 bootstrap samples (B) will be drawn. For each bootstrap iteration, simultaneous randomized realization of each of these modeled distributions will be used to build the data necessary for a Darroch model. After drawing the distribution of recovered marks for each stratum, the total number of marks deployed will be adjusted down by the bootstrap estimates of handling and tag loss. The bootstrap realization of number of "unrecovered" marks for that stratum will also be adjusted downward accordingly (by subtraction). We will then calculate an estimate of $\hat{N}$ for each of the B bootstrap samples using the methods describe in section 11.1 of Seber (1982). Equation 5 will be used to estimate the variance of the abundance estimate. Application of the methods in section 11.1 of Seber (1982) will also simultaneously provide estimates of the number of fish in each of the s marking strata ($\hat{N}_s$) and each of the t second event strata.

Sonar Passage Estimates of Chinook Salmon

The following procedures will be used to estimate the number of Chinook salmon greater than or equal to 500mm METF that migrate upstream past the sonar site. Estimates of total length (TL) will be made from images of all fish exceeding approximately 400 mm TL. True TL of each of these images will be predicted using the relationship based on tethered fish described in Miller et al. (2011, see Fig. 25).

A model predicting METF from TL will be developed based on measurements of Chinook salmon collected at a weir/sonar site using linear regression techniques (Neter et al. 1985; Appendix G1). This model will be used to convert TL predictions from ARIS images to METF predictions.

Estimates of Chinook salmon passage will be stratified by day. Daily estimates of passage will be considered a direct expansion from counts during 10 min counting periods where each of 3 insonification zones (distances from the transducer) are counted sequentially during each 30 minute period during a day. These counts are considered systematic sampling because the 10 min counting periods are not chosen randomly.

The formulas necessary to estimate passage from sonar count data are taken directly or modified from those provided in Cochran (1977). The expanded passage on day d will be estimated using

$$\hat{C}_d = \frac{M_d}{m_d} \sum_{j=1}^{m_d} y_{dj} \tag{5}$$

where

d = day;

j = 30-min counting period during which each insonification zone is counted for 10 minutes;

y_{dj} = observed net upstream movement (sum over the three 10-min counts from each insonification zone of upstream minus downstream counts) during the 30 min counting period j;

m_d = number of 30-min counting periods sampled within a day (typically 48);

M_d = total number of possible 10-min counting periods within a day (144);

The variance for the expanded daily escapement will be estimated using the successive difference approach:

$$\hat{V}(\hat{C}_d) = \left(\frac{M_d - m_d}{M_d}\right)\frac{M_d^2}{m_d}\frac{1}{2(m_d - 1)}\sum_{j=2}^{m_d}\left(y_{dj} - y_{d(j-1)}\right)^2 . \quad (6)$$

A correction may need to be applied to observed counts (y_{dj}) if movement of species other than Chinook salmon are detected at the sonar site late in the Chinook salmon run.

For sonar images collected prior to detection of salmon species other than Chinook salmon, the passage of Chinook salmon ≥500mm will be estimated as the sum of all METF predictions from ARIS images that satisfy this criterion. In 2013, no passage of salmon species other than Chinook salmon was detected prior to the data when sonar counting was terminated.

For sonar images collected after other salmon species are detected at the sonar site, the procedures described in Appendix G1 will be used to create METF predictions from ARIS images. Size composition data for Chinook salmon collected at the sonar site will be examined using contingency table analysis to test the hypothesis that the proportions of Chinook salmon 500 mm–699 mm to those greater than or equal to 700 mm METF are independent of week or quartile when collected. The most recent portion of the data for which this relationship is relatively homogeneous will be used to estimate

$$\hat{p}_{700+,i} = n_{700+,i} \big/ n_{500+,i} \quad (7)$$

where $n_{500+,i}$ = total number of Chinook salmon sampled at site *i* that were greater than or equal to 500 mm METF, and $n_{700+,i}$ = those members of $n_{500+,i}$ that were greater than or equal to 700 mm METF. The number of DIDSON images with predicted METF

greater than or equal to 700 mm will be tallied to create $\hat{C}_{700+,i}$, and we will estimate the number of Chinook salmon greater than or equal to 500 mm METF using the following:

$$\hat{C}_{500+,i} = \hat{C}_{700+,i} \big/ \hat{p}_{700+,i} . \quad (8)$$

To estimate variance, the data used for Equation 7 will be modeled as a binomial process to create a bootstrap sample of $\hat{p}_{700+,i}$. This bootstrap sample will be used in concert with the bootstrap procedures described above to create a bootstrap sample of the parameter $\hat{C}_{500+,i}$ and variance will be calculated using Equation 4.

SPAWNING LOCATION

The fixed telemetry station at the lower Yentna River and 1 mile upstream of the Susitna River mainstem fish wheel site will be used as the gateway to the experiment for spawning location for all species. Fish that do not pass the gateway will be noted and will not be used to characterize spawning distribution. Prior to determining spawning sites, all "lost" (including harvested fish)

radiotagged fish will be identified and censored. Tag loss or fish mortality will be assumed for any tag that transmits an "inactive" code and for which upstream movement has ceased prior to reaching potential spawning areas. All tags that move downstream immediately after tagging and are not later detected moving upstream will be assumed to be handling mortalities; i.e., those that do not pass the gateway. Significant variations in fish mortality or tag loss over time and tagging site will be used to identify possible needs for changes in fish handling.

Following removal of "lost" tags, a final location will be determined for each tagged fish using the telemetry data. Radio tags deployed and relocated by date, species, and fish wheel (also gillnet for Chinook salmon) will be tabulated. In most cases, the furthest upstream locations of a radiotagged fish will be assumed to be the actual spawning site or spawning drainage. However, in very few circumstances some judgment may be exercised to deviate from this guideline. For example, if following the extreme upstream location, a fish is later observed to spend more than 2 weeks (anticipated interval between aerial surveys) in a further downstream location or another tributary in the presence of other spawning fish, the latter site will be used rather than the extreme upstream location.

A map of the final locations of tagged fish by species and fish wheel will be constructed. Visually comparing final locations between fish wheels may be useful in detecting bank orientation, which must be considered when planning future experiments, especially for Chinook salmon.

SPAWNING DISTRIBUTION

For Chinook and coho salmon only, the diagnostic procedures described in Appendix E2 will be used to detect evidence of geographic or temporal variability in probability of capture during the marking event. The test results will guide stratification of groups of marked fish into S temporally and geographically contiguous strata, such that little or no evidence of variation in probability of capture is detectable within strata. A Darroch (1961) model, with $s = t$, will be used to estimate the total number of fish passing the marking sites within each marking stratum $\hat{N}_s$ (as described above). These estimates will not be mutually independent.

For each marking stratum, radiotagging data will be used to estimate spawning distribution

$$\hat{p}_{l,s} = n_{l,s} / n_s \tag{9}$$

where $\hat{p}_{l,s} = n_{l,s} / n_s$ is the estimated proportion of salmon from stratum s spawning in location l, n_s is the number of fish radiotagged in stratum s that travelled to a spawning location, and $n_{l,s}$ is the number of fish from n_s that travelled to location l.

The total number of salmon spawning in location l can be estimated as

$$\hat{N}_l = \sum_{s=1}^{S} \hat{N}_s \hat{p}_{l,s} \tag{10}$$

and the proportion of salmon spawning in each location estimated as

$$\hat{p}_l = \hat{N}_l \Big/ \sum_{s=1}^{S} \hat{N}_s \, . \tag{11}$$

Variance for these parameters will be estimated using bootstrap procedures (Buckland and Garthwaite 1991). Variation in estimates of spawning distribution parameters within each of S strata will be modeled using multinomial distributions and the observed data described in Equation 9.

A minimum of 1,000,000 bootstrap samples (B) will be drawn for spawning distribution for each marking stratum. Equations 10 and 11 will then be used to provide a bootstrap estimate of spawning distribution proportions. Variance for each of these parameters will then be estimated using methods analogous to Equation 4.

GENETICS SAMPLES

Tissue samples will be collected by SF personnel and transferred to CF at the end of the field season. All genetics sample processing, data storage, and data analysis will be the responsibility of the ADF&G Gene Conservation Lab in Anchorage.

SCHEDULE AND DELIVERABLES

1. Deploy fixed radio tracking stations 19 May–10 June, 2014
2. Download fixed radio tracking stations approximately every 1–3 weeks, 1 June–30 September 2014
3. Radio telemetry aerial surveys approximately every 2 weeks, 23 June–30 September 2014
4. Marking operations at the mainstem Susitna River and Yentna RM 7 sites approximately 22 May–30 August 2014
5. Sonar sampling at middle fork Chulitna River approximately 10 June–31 July 2014
6. Recapture sampling at Yentna RM 18.8 site approximately 22 May–30 August 2014
7. Weir sampling at Deshka River and Montana Creek approximately 19 May (Deshka) and 10 June (Montana) through 5 September 2014
8. Data reduction and analysis 15 September–31 December 2014
9. Final 2014 Fishery Data Series Report 30 November 2015
10. Genetics results will be reported separately, to be determined by ADF&G Gene Conservation Lab

RESPONSIBILITIES

Pete Cleary (Fishery Biologist II):

Supervise Mainstem Susitna and Yentna operations and Montana Creek weir and sonar operations the MF of the Chulitna River. Oversee all SF fish wheel portions of project: planning, budgeting, hiring and training field staff, data collection, editing and analysis, supervision, and purchasing. Coordinate with John Campbell on radio tag deployment. Lead author on operational plan and report.

John Campbell (Fishery Biologist II):

Lead all radio telemetry and tracking portions of project: planning, budgeting, data collection, data analysis, purchasing, reporting, crew training, radio tracking station setup and downloads, and aerial surveys. Assist with hiring and training and writing the operational plan. Coauthor on report.

Dan Reed (Biometrician III), David Evans (Biometrician III):

Advise all portions of the biometrics: planning, sample sizes, statistical methods, and data analysis.

Gayle Horner-Neufeld (Research Analyst):

Import raw telemetry and tag data into SQL database, write appropriate queries.

Andy Barclay (Geneticist):

Advice on portions of the genetics: planning, sample sizes, statistical methods, data analysis, and reporting. Supply tissue collection materials and instructions.

Mark Willette (Fishery Biologist III):

Oversee all Yentna portions of project: planning, budgeting, hiring and training field staff, supervision, and purchasing. Provide sampling data from Yentna.

Richard Yanusz (Fishery Biologist III):

Review all aspects of project: planning, budget, data collection, data analysis, and reporting.

Steve Dotomain (Fishery Biologist I):

Assist with all aspects at the mainstem Susitna site: planning, budgeting, hiring and training field staff, data collection, data analysis, supervision, and purchasing. Assist with radio telemetry data collection as needed. Conduct logistics for weir and sonar field camps

vacant (Fishery Biologist I):

Assist with all aspects of the Yentna River recapture site: planning, budgeting, hiring and training field staff, data collection, data analysis, supervision, and purchasing. Assist with radio telemetry data collection as needed. Assist with for weir and sonar field camps as needed . Conduct logistics for weir and sonar field camps.

Taylor Hendricks (Fish and Wildlife Technician III):

Assist with field work to collect radio telemetry data.

James Striberny (Fish and Wildlife Technician III):

Conduct field camp supervision and field sampling at the Mainstem Susitna camp according to operational plan and verbal instructions.

Luke Warta (Fish and Wildlife Technician III):

Conduct field camp supervision and field sampling at the Yentna River recapture camp according to operational plan and verbal instructions.

Technicians (Fish and Wildlife Technician II or III, College Intern II):

Conduct field sampling at Yentna and mainstem Susitna River sites according to operational plan and verbal instructions.

REFERENCES CITED

ADF&G Chinook Salmon Research Team. 2013. Chinook salmon stock assessment and research plan, 2013. Alaska Department of Fish and Game, Special Publication No. 13-01, Anchorage.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences. 2106: 37 p.

Buckland, S. T. and P. H. Garthwaite. 1991. Quantifying precision of mark-recapture estimates using bootstrap and related methods. Biometrics 47:255-268.

Carlon, J., and D. Evans. 2007. Abundance of Adult Coho Salmon in the Kenai River, Alaska, 1999-2003. Alaska Department of Fish and Game, Fishery Data Series No. 07-81, Anchorage.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publication Station 1:131-160.

Cleary P., R. A. Merizon, R. J. Yanusz, and, D. J. Reed. 2013. Abundance and Spawning Distribution of Susitna River chum. *Oncorhynchus keta* and coho *O. kisutch* salmon, 2010. Alaska Department of Fish and Game, Fishery Data Series No. 13-05, Anchorage.

Darroch, J.N. 1961. Two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48: 241-60.

Efron, B. I. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall. New York.

Larson, L. 1995. A portable restraint cradle for handling large salmonids. North American Journal of Fisheries Management 15:654-656.

Merizon. R., R. Yanusz, D. Reed, and T. Spencer. 2010. Distribution of Spawning Susitna River Chum *Oncorhynchus keta* and Coho Salmon *O. kisutch*, 2009. Alaska Department of Fish and Game, Fishery Data Series Report. 10-72. Anchorage.

Miller, J. D., D. L. Burwen, and Steve J. Fleischman. 2011. Estimates of Chinook salmon passage in the Kenai River using split-beam sonar, 2007. Alaska Department of Fish and Game, Fishery Data Series No. 11-52, Anchorage.

Neter, J. W. Wasserman, and M. H. Kutner. 1985. Applies linear statistical models 2nd ed. Richard D. Irwin, Inc., Homewood, Illinois.

Robson, D. S. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Trans.Amer. Fish. Soc. 93:215-226.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters. 2nd. ed. Charles Griffin and Sons, Ltd., London. 654 p.

Shields, P. 2007. Upper Cook Inlet Commercial Fisheries Annual Management Report, 2007. Alaska Department of Fish and Game, Fishery Management Report No. 07-64, Anchorage.

Smith, J., and D. Robichaud, K. K. English, and P. Johnson. 2007. Feasibility of fishwheel use for escapement estimation and results from salmon radio-tracking on the lower Fraser River in 2008. LGL Limited, Sidney, British Columbia.

Thompson, F. M., S. N. Wick, and B. L. Stratton. 1986. Adult salmon investigations May – October 1985. Alaska Department of Fish and Game, Susitna Hydro Aquatic Studies Report Series 13, Anchorage.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician. 41:42-46.

Underwood, Tevis J., J.F. Bromaghin, and S.P. Klowiewski. 2004. Evidence of Handling Mortality of Adult Chum Salmon Caused by Fish Wheel Capture in the Yukon River, Alaska. North American Journal of Fisheries Management 24:237-243.

Willette, T. M., R. DeCino, and N. Gove. 2003. Mark-recapture population estimates of coho, pink, and chum salmon runs to upper Cook Inlet in 2002. Alaska Department of Fish and Game, Regional Information Report No. 2A03-20, Anchorage.

Yanusz, R., R. Merizon, D. Evans, M. Willette, T. Spencer, and S. Raborn. 2007. Inriver Abundance and Distribution of Spawning Susitna River Sockeye Salmon *Oncorhynchus nerka*, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-83, Anchorage.

TABLES

Table 1.–Crew schedule for fishing drift gillnets and the radio tag deployment schedule at the mainstem Susitna and Yentna rivers marking sites.

	Morning		Afternoon			
Date	Start	Stop	Start	Stop	Daily radios	Tags/Shift
22-May	9:00	12:45	17:00	20:45	1	morning
23-May	8:00	11:45	16:00	19:45	1	afternoon
24-May	7:00	10:45	15:00	18:45	1	morning
25-May	6:00	9:45	14:00	17:45	1	afternoon
26-May	7:00	10:45	15:00	18:45	1	morning
27-May	8:00	11:45	16:00	19:45	1	afternoon
28-May	9:00	12:45	17:00	20:45	2	both
29-May	10:00	13:45	18:00	21:45	2	both
30-May	11:00	14:45	19:00	22:45	3	morning =2
31-May	12:00	15:45	20:00	23:45	3	afternoon =2
1-Jun	11:00	14:45	19:00	22:45	4	both
2-Jun	10:00	13:45	18:00	21:45	4	both
3-Jun	9:00	12:45	17:00	20:45	5	morning = 3
4-Jun	8:00	11:45	16:00	19:45	5	morning =2
5-Jun	7:00	10:45	15:00	18:45	5	morning = 3
6-Jun	6:00	9:45	14:00	17:45	5	morning =2
7-Jun	7:00	10:45	15:00	18:45	5	morning = 3
8-Jun	8:00	11:45	16:00	19:45	5	morning = 2
9-Jun	9:00	12:45	17:00	20:45	5	morning = 3
10-Jun	10:00	13:45	18:00	21:45	5	morning = 2
11-Jun	11:00	14:45	19:00	22:45	4	both
12-Jun	12:00	15:45	20:00	23:45	4	both
13-Jun	11:00	14:45	19:00	22:45	4	both
14-Jun	10:00	13:45	18:00	21:45	4	both
15-Jun	9:00	12:45	17:00	20:45	4	both
16-Jun	8:00	11:45	16:00	19:45	3	morning = 1
17-Jun	7:00	10:45	15:00	18:45	3	morning = 2
18-Jun	6:00	9:45	14:00	17:45	2	both
19-Jun	7:00	10:45	15:00	18:45	2	both
20-Jun	8:00	11:45	16:00	19:45	1	afternoon
21-Jun	9:00	12:45	17:00	20:45	0	
22-Jun	10:00	13:45	18:00	21:45	1	morning
23-Jun	11:00	14:45	19:00	22:45	0	
24-Jun	12:00	15:45	20:00	23:45	1	afternoon
25-Jun	11:00	14:45	19:00	22:45	0	
26-Jun	10:00	13:45	18:00	21:45	1	morning
27-Jun	9:00	12:45	17:00	20:45	0	
28-Jun	8:00	11:45	16:00	19:45	1	afternoon
29-Jun	7:00	10:45	15:00	18:45	0	
30-Jun	6:00	9:45	14:00	17:45	1	morning

Table 2.–The 2014 mainstem Susitna River Chinook salmon radiotagging schedule by fish wheel and gillnet.

	Fish Wheel 1		Fish Wheel 2		Gillnet	
Date	Shift #1	Shift #2	Shift #1	Shift #2	Morning	Evening
22-May	1	1	1	1	1	0
23-May	1	0	0	1	0	1
24-May	1	1	1	1	1	0
25-May	0	1	1	0	0	1
26-May	2	1	1	2	1	0
27-May	2	3	3	2	0	1
28-May	3	3	3	3	1	1
29-May	4	3	3	4	1	1
30-May	4	5	5	4	2	1
31-May	6	5	5	6	1	2
1-Jun	6	6	6	6	2	2
2-Jun	6	7	7	6	2	2
3-Jun	7	8	8	7	3	2
4-Jun	8	7	7	8	2	3
5-Jun	7	8	8	7	3	2
6-Jun	8	7	7	8	2	3
7-Jun	7	8	8	7	3	2
8-Jun	8	7	7	8	2	3
9-Jun	7	8	8	7	3	2
10-Jun	8	7	7	8	2	3
11-Jun	7	7	7	7	2	2
12-Jun	7	6	6	7	2	2
13-Jun	7	7	7	7	2	2
14-Jun	6	6	6	6	2	2
15-Jun	5	5	5	5	2	2
16-Jun	4	5	5	4	2	1
17-Jun	4	4	4	4	1	2
18-Jun	3	3	3	3	1	1
19-Jun	2	2	2	2	1	1
20-Jun	2	1	1	2	1	0
21-Jun	0	1	1	0	0	0
22-Jun	1	1	1	1	0	1
23-Jun	1	0	0	1	0	0
24-Jun	1	1	1	1	1	0
25-Jun	0	1	1	0	0	0
26-Jun	1	1	1	1	0	1
27-Jun	1	0	0	1	0	0
28-Jun	1	1	1	1	1	0
29-Jun	0	1	1	0	0	0
30-Jun	1	1	1	1	0	1
Total Tags	150	150	150	150	50	50

Table 3.–The 2014 mainstem Susitna River coho and pink salmon radiotagging schedule by fish wheel (FW).

	Coho			Pink		
Date	FW1	FW2	Total	FW1	FW2	Total
6-Jul	0	0	0	0	0	0
7-Jul	3	3	6	0	0	0
8-Jul	3	3	6	0	0	0
9-Jul	3	3	6	0	0	0
10-Jul	6	6	12	0	0	0
11-Jul	3	3	6	0	0	0
12-Jul	6	6	12	0	0	0
13-Jul	6	6	12	0	0	0
14-Jul	6	6	12	1	1	2
15-Jul	12	12	24	0	0	0
16-Jul	12	12	24	1	1	2
17-Jul	9	9	18	1	1	2
18-Jul	9	9	18	3	3	6
19-Jul	6	6	12	3	3	6
20-Jul	6	6	12	4	4	8
21-Jul	12	12	24	4	4	8
22-Jul	12	12	24	4	4	8
23-Jul	12	12	24	6	6	12
24-Jul	9	9	18	8	8	16
25-Jul	15	15	30	9	9	18
26-Jul	12	12	24	7	7	14
27-Jul	9	9	18	6	6	12
28-Jul	9	9	18	6	6	12
29-Jul	12	12	24	6	6	12
30-Jul	9	9	18	5	5	10
31-Jul	9	9	18	4	4	8
1-Aug	9	9	18	4	4	8
2-Aug	9	9	18	4	4	8
3-Aug	9	9	18	2	2	4
4-Aug	9	9	18	1	1	2
5-Aug	9	9	18	1	1	2
6-Aug	9	9	18	1	1	2
7-Aug	6	6	12	1	1	2
8-Aug	6	6	12	1	1	2
9-Aug	6	6	12	1	1	2
10-Aug	3	3	6	1	1	2
11-Aug	6	6	12	1	1	2
12-Aug	3	3	6	1	1	2
13-Aug	0	0	0	1	1	2
14-Aug	0	0	0	1	1	2
15-Aug	3	3	6	0	0	0
16-Aug	0	0	0	1	1	2
17-Aug	0	0	0	0	0	0
18-Aug	0	0	0	0	0	0
19-Aug	0	0	0	0	0	0
20-Aug	3	3	6	0	0	0
21-Aug	0	0	0	0	0	0
22-Aug	0	0	0	0	0	0
23-Aug	0	0	0	0	0	0
24-Aug	0	0	0	0	0	0
25-Aug	0	0	0	0	0	0
26-Aug	0	0	0	0	0	0
27-Aug	0	0	0	0	0	0
28-Aug	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0
30-Aug	0	0	0	0	0	0
31-Aug	0	0	0	0	0	0
1-Sep	0	0	0	0	0	0
Totals	300	300	600	100	100	200

Table 4.–The 2014 Yentna River Chinook salmon radiotagging schedule by fish wheel and gillnet. Fish wheel 1 is near the south bank, and fish wheel 2 is near the north bank.

	Fish Wheel 1		Fish Wheel 2		Gillnet	
Date	Shift #1	Shift #2	Shift #1	Shift #2	Morning	Evening
22-May	1	0	0	1	1	0
23-May	0	1	1	0	0	1
24-May	1	0	0	1	1	0
25-May	0	1	1	0	0	1
26-May	1	0	0	1	1	0
27-May	0	1	1	0	0	1
28-May	1	1	1	1	1	1
29-May	1	1	1	1	1	1
30-May	2	1	1	2	2	1
31-May	1	2	2	1	1	2
1-Jun	2	2	2	2	2	2
2-Jun	2	2	2	2	2	2
3-Jun	3	2	2	3	3	2
4-Jun	2	3	3	2	2	3
5-Jun	3	2	2	3	3	2
6-Jun	2	3	3	2	2	3
7-Jun	3	2	2	3	3	2
8-Jun	2	3	3	2	2	3
9-Jun	3	2	2	3	3	2
10-Jun	2	3	3	2	2	3
11-Jun	2	2	2	2	2	2
12-Jun	2	2	2	2	2	2
13-Jun	2	2	2	2	2	2
14-Jun	2	2	2	2	2	2
15-Jun	2	2	2	2	2	2
16-Jun	2	1	1	2	2	1
17-Jun	1	2	2	1	1	2
18-Jun	1	1	1	1	1	1
19-Jun	1	1	1	1	1	1
20-Jun	1	0	0	1	1	0
21-Jun	0	0	0	0	0	0
22-Jun	0	1	1	0	0	1
23-Jun	0	0	0	0	0	0
24-Jun	1	0	0	1	1	0
25-Jun	0	0	0	0	0	0
26-Jun	0	1	1	0	0	1
27-Jun	0	0	0	0	0	0
28-Jun	1	0	0	1	1	0
29-Jun	0	0	0	0	0	0
30-Jun	0	1	1	0	0	1
Total Tags	50	50	50	50	50	50

Table 5.–The 2014 Yentna River coho salmon radiotagging schedule by fish wheel. Fish wheel 1 is near the south bank and fish wheel 2 is near the north bank.

Date	Fish Wheel 1	Fish Wheel 2	Total
6-Jul	0	0	0
7-Jul	0	0	0
8-Jul	0	0	0
9-Jul	1	1	2
10-Jul	0	0	0
11-Jul	0	0	0
12-Jul	1	1	2
13-Jul	1	1	2
14-Jul	1	1	2
15-Jul	1	1	2
16-Jul	1	1	2
17-Jul	1	1	2
18-Jul	1	1	2
19-Jul	0	0	0
20-Jul	1	1	2
21-Jul	1	1	2
22-Jul	1	1	2
23-Jul	1	1	2
24-Jul	1	1	2
25-Jul	2	2	4
26-Jul	1	1	2
27-Jul	1	1	2
28-Jul	1	1	2
29-Jul	1	1	2
30-Jul	1	1	2
31-Jul	1	1	2
1-Aug	1	1	2
2-Aug	1	1	2
3-Aug	1	1	2
4-Aug	1	1	2
5-Aug	1	1	2
6-Aug	0	0	0
7-Aug	1	1	2
8-Aug	0	0	0
9-Aug	1	1	2
10-Aug	0	0	0
11-Aug	1	1	2
12-Aug	0	0	0
13-Aug	0	0	0
14-Aug	0	0	0
15-Aug	1	1	2
16-Aug	0	0	0
17-Aug	0	0	0
18-Aug	0	0	0
19-Aug	0	0	0
20-Aug	0	0	0
Totals	30	30	60

Table 6.–Fixed radiotracking station locations throughout the mainstem Susitna River and Yentna River drainages, 2014.

Drainage	Site Name	Latitude	Longitude
Yentna	Lower Yentna	61.66359	-150.62567
	Skwentna	61.87268	-151.35259
	Upper Yentna	62.19382	-151.58783
Susitna	Deshka Mouth	61.69127	-150.30632
	Sunshine	62.17300	-150.17428
	Talkeetna	62.34754	-150.01463
	Chulitna (Princess Lodge)	62.55397	-150.23167
	Deshka Weir	61.78585	-150.34572
	Montana Creek Weir	62.10556	-150.04861
	Middle Fork Chulitna Sonar	63.05900	-149.58222

Datum is WGS84

FIGURES

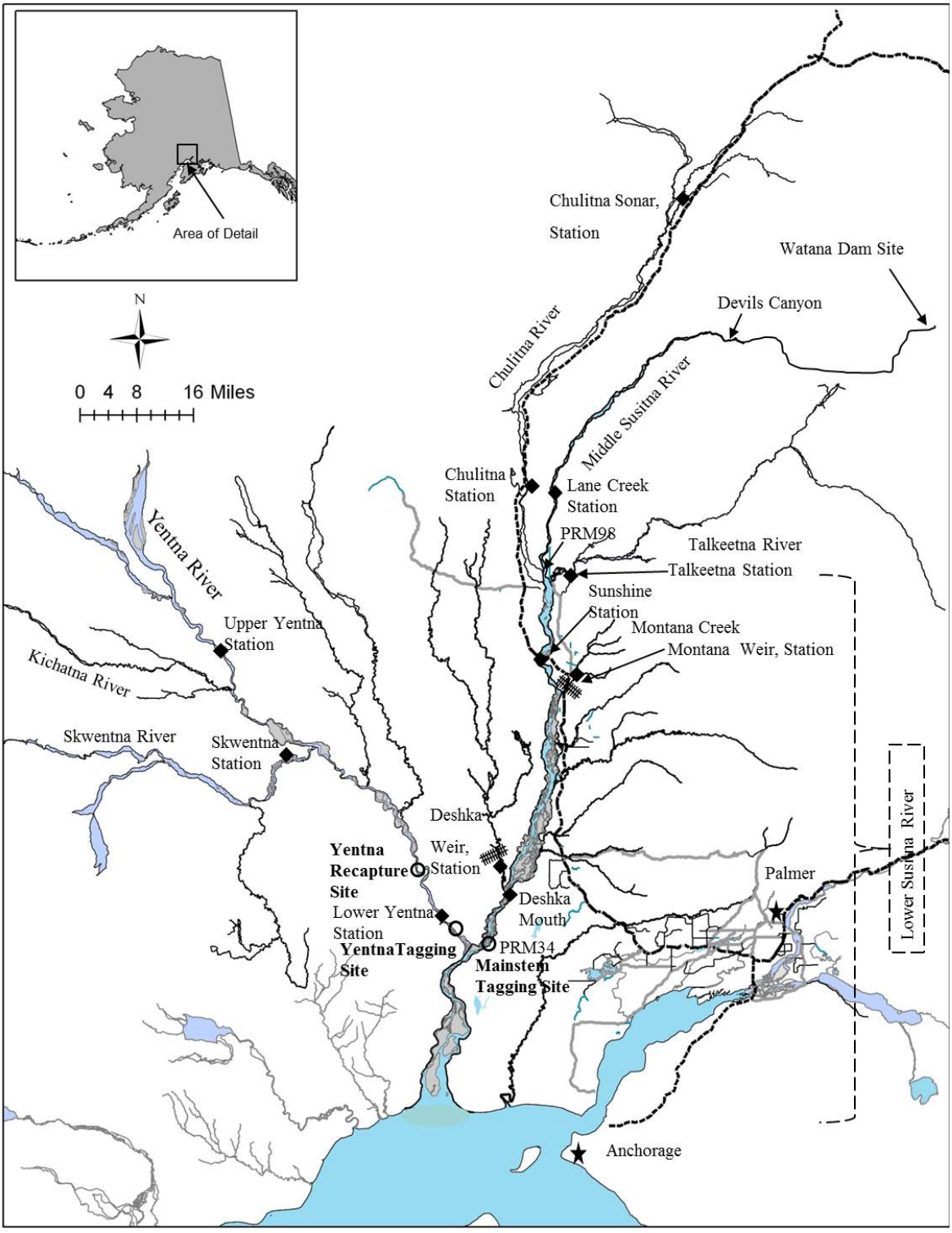


Figure 1.–Fish wheel sites (open circles) for Chinook, coho, and pink salmon, fixed radiotracking stations (diamonds), weir/sonar sites (fences), and the proposed Watana dam site in the Susitna River, Alaska.

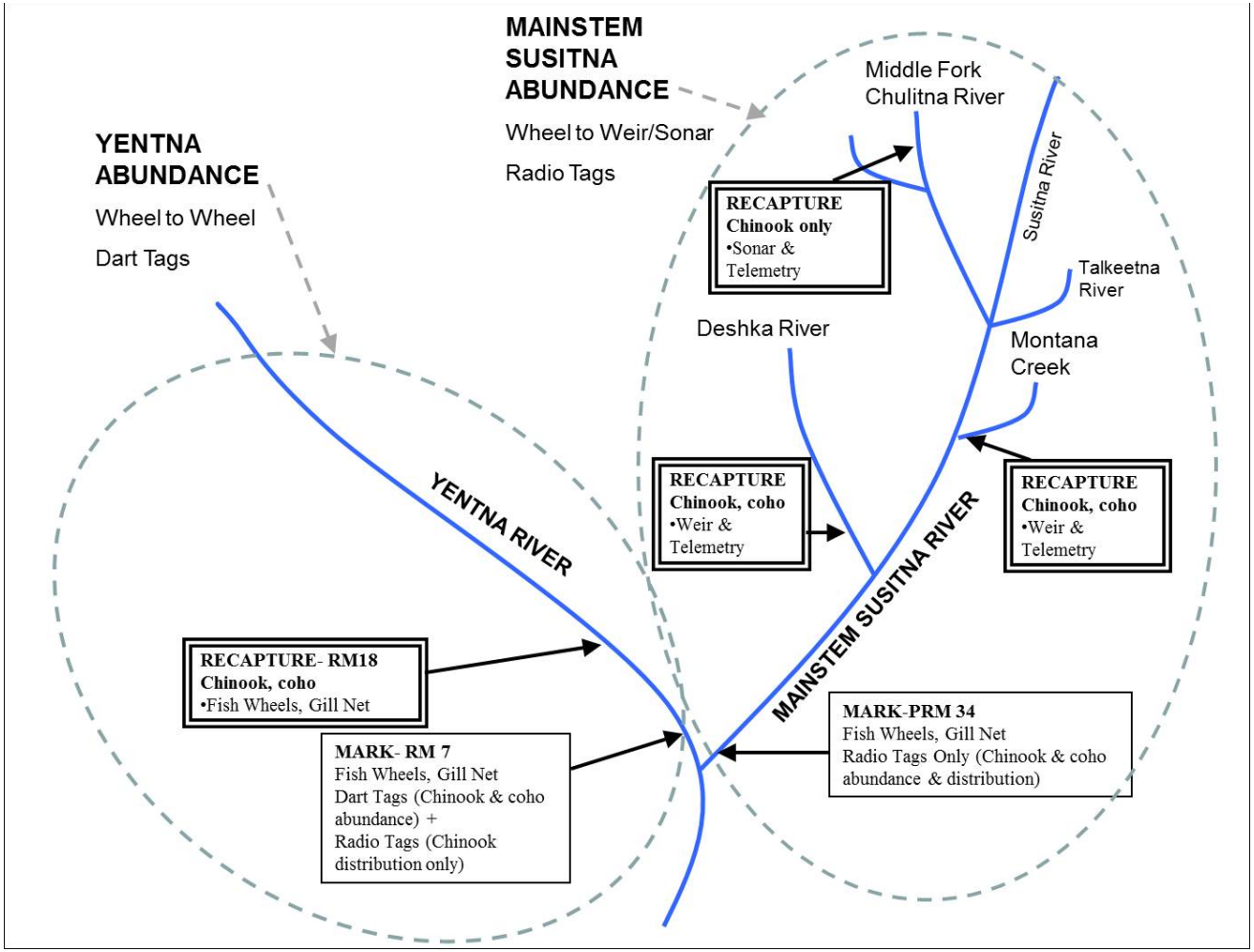


Figure 2.–Sampling design for the mainstem Susitna and Yentna rivers mark–recapture experiments.

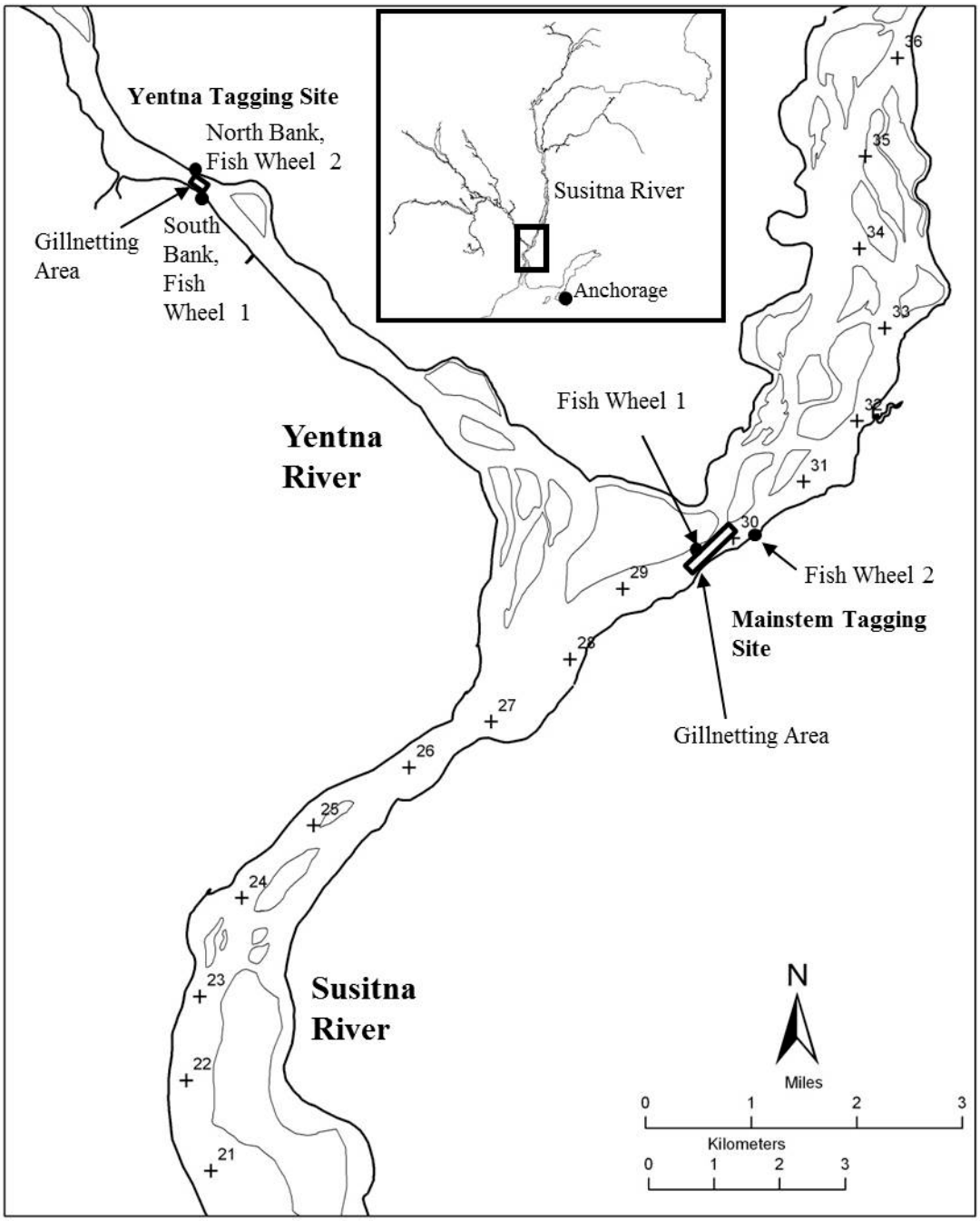


Figure 3.–Tagging sites and river miles.

APPENDIX A: FISH WHEEL SHIFT SCHEDULES AND RADIO TAG DEPLOYMENT LOG

Appendix A1.–Fish wheel shift schedules at the mainstem Susitna River tagging site, 2014.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
22-May	500	1300	1400	2200	Shift 1	Shift 2
23-May	500	1300	1400	2200	Shift 1	Shift 2
24-May	500	1300	1400	2200	Shift 1	Shift 2
25-May	500	1300	1400	2200	Shift 1	Shift 2
26-May	500	1300	1400	2200	Shift 1	Shift 2
27-May	500	1300	1400	2200	Shift 1	Shift 2
28-May	500	1300	1400	2200	Shift 1	Shift 2
29-May	500	1300	1400	2200	Shift 1	Shift 2
30-May	500	1300	1400	2200	Shift 1	Shift 2
31-May	500	1300	1400	2200	Shift 1	Shift 2
1-Jun	500	1300	1400	2200	Shift 1	Shift 2
2-Jun	500	1300	1400	2200	Shift 1	Shift 2
3-Jun	500	1300	1400	2200	Shift 1	Shift 2
4-Jun	500	1300	1400	2200	Shift 1	Shift 2
5-Jun	500	1300	1400	2200	Shift 2	Shift 1
6-Jun	500	1300	1400	2200	Shift 2	Shift 1
7-Jun	500	1300	1400	2200	Shift 2	Shift 1
8-Jun	500	1300	1400	2200	Shift 2	Shift 1
9-Jun	500	1300	1400	2200	Shift 2	Shift 1
10-Jun	500	1300	1400	2200	Shift 2	Shift 1
11-Jun	500	1300	1400	2200	Shift 2	Shift 1
12-Jun	500	1300	1400	2200	Shift 2	Shift 1
13-Jun	500	1300	1400	2200	Shift 2	Shift 1
14-Jun	500	1300	1400	2200	Shift 2	Shift 1
15-Jun	500	1300	1400	2200	Shift 2	Shift 1
16-Jun	500	1300	1400	2200	Shift 2	Shift 1
17-Jun	500	1300	1400	2200	Shift 2	Shift 1
18-Jun	500	1300	1400	2200	Shift 2	Shift 1
19-Jun	500	1300	1400	2200	Shift 1	Shift 2
20-Jun	500	1300	1400	2200	Shift 1	Shift 2
21-Jun	500	1300	1400	2200	Shift 1	Shift 2
22-Jun	500	1300	1400	2200	Shift 1	Shift 2
23-Jun	500	1300	1400	2200	Shift 1	Shift 2
24-Jun	500	1300	1400	2200	Shift 1	Shift 2
25-Jun	500	1300	1400	2200	Shift 1	Shift 2
26-Jun	500	1300	1400	2200	Shift 1	Shift 2
27-Jun	500	1300	1400	2200	Shift 1	Shift 2
28-Jun	500	1300	1400	2200	Shift 1	Shift 2
29-Jun	500	1300	1400	2200	Shift 1	Shift 2
30-Jun	500	1300	1400	2200	Shift 1	Shift 2

Continued

Appendix A1.–Page 2 of 3.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
1-Jul	500	1300	1400	2200	Shift 1	Shift 2
2-Jul	500	1300	1400	2200	Shift 1	Shift 2
3-Jul	500	1300	1400	2200	Shift 2	Shift 1
4-Jul	500	1300	1400	2200	Shift 2	Shift 1
5-Jul	500	1300	1400	2200	Shift 2	Shift 1
6-Jul	500	1300	1400	2200	Shift 2	Shift 1
7-Jul	500	1300	1400	2200	Shift 2	Shift 1
8-Jul	500	1300	1400	2200	Shift 2	Shift 1
9-Jul	500	1300	1400	2200	Shift 2	Shift 1
10-Jul	500	1300	1400	2200	Shift 2	Shift 1
11-Jul	500	1300	1400	2200	Shift 2	Shift 1
12-Jul	500	1300	1400	2200	Shift 2	Shift 1
13-Jul	500	1300	1400	2200	Shift 2	Shift 1
14-Jul	500	1300	1400	2200	Shift 2	Shift 1
15-Jul	500	1300	1400	2200	Shift 2	Shift 1
16-Jul	500	1300	1400	2200	Shift 2	Shift 1
17-Jul	500	1300	1400	2200	Shift 2	Shift 1
18-Jul	500	1300	1400	2200	Shift 1	Shift 2
19-Jul	500	1300	1400	2200	Shift 1	Shift 2
20-Jul	500	1300	1400	2200	Shift 1	Shift 2
21-Jul	500	1300	1400	2200	Shift 1	Shift 2
22-Jul	500	1300	1400	2200	Shift 1	Shift 2
23-Jul	500	1300	1400	2200	Shift 1	Shift 2
24-Jul	500	1300	1400	2200	Shift 1	Shift 2
25-Jul	500	1300	1400	2200	Shift 1	Shift 2
26-Jul	500	1300	1400	2200	Shift 1	Shift 2
27-Jul	500	1300	1400	2200	Shift 1	Shift 2
28-Jul	500	1300	1400	2200	Shift 1	Shift 2
29-Jul	500	1300	1400	2200	Shift 1	Shift 2
30-Jul	500	1300	1400	2200	Shift 1	Shift 2

Continued

Appendix A1.–Page 3 of 3.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
1-Aug	500	1300	1400	2200	Shift 1	Shift 2
2-Aug	300	1200	1400	2300	Shift 2	Shift 1
3-Aug	300	1200	1400	2300	Shift 2	Shift 1
4-Aug	300	1200	1400	2300	Shift 2	Shift 1
5-Aug	300	1200	1400	2300	Shift 2	Shift 1
6-Aug	300	1200	1400	2300	Shift 2	Shift 1
7-Aug	300	1200	1400	2300	Shift 2	Shift 1
8-Aug	300	1200	1400	2300	Shift 2	Shift 1
9-Aug	300	1200	1400	2300	Shift 2	Shift 1
10-Aug	300	1200	1400	2300	Shift 2	Shift 1
11-Aug	300	1200	1400	2300	Shift 2	Shift 1
12-Aug	300	1200	1400	2300	Shift 2	Shift 1
13-Aug	300	1200	1400	2300	Shift 2	Shift 1
14-Aug	300	1200	1400	2300	Shift 2	Shift 1
15-Aug	300	1200	1400	2300	Shift 2	Shift 1
16-Aug	300	1200	1400	2300	Shift 1	Shift 2
17-Aug	300	1200	1400	2300	Shift 1	Shift 2
18-Aug	300	1200	1400	2300	Shift 1	Shift 2
19-Aug	300	1200	1400	2300	Shift 1	Shift 2
20-Aug	300	1200	1400	2300	Shift 1	Shift 2
21-Aug	300	1200	1400	2300	Shift 1	Shift 2
22-Aug	300	1200	1400	2300	Shift 1	Shift 2
23-Aug	300	1200	1400	2300	Shift 1	Shift 2
24-Aug	300	1200	1400	2300	Shift 1	Shift 2
25-Aug	300	1200	1400	2300	Shift 1	Shift 2
26-Aug	300	1200	1400	2300	Shift 1	Shift 2
27-Aug	300	1200	1400	2300	Shift 1	Shift 2
28-Aug	300	1200	1400	2300	Shift 1	Shift 2

Appendix A2.–Fish wheel shift schedules at the Yentna River tagging site, 2014.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
22-May	300	1200	1400	2300	Shift 1	Shift 2
23-May	300	1200	1400	2300	Shift 1	Shift 2
24-May	300	1200	1400	2300	Shift 1	Shift 2
25-May	300	1200	1400	2300	Shift 1	Shift 2
26-May	300	1200	1400	2300	Shift 1	Shift 2
27-May	300	1200	1400	2300	Shift 1	Shift 2
28-May	300	1200	1400	2300	Shift 1	Shift 2
29-May	300	1200	1400	2300	Shift 1	Shift 2
30-May	300	1200	1400	2300	Shift 1	Shift 2
31-May	300	1200	1400	2300	Shift 1	Shift 2
1-Jun	300	1200	1400	2300	Shift 1	Shift 2
2-Jun	300	1200	1400	2300	Shift 1	Shift 2
3-Jun	300	1200	1400	2300	Shift 1	Shift 2
4-Jun	300	1200	1400	2300	Shift 1	Shift 2
5-Jun	300	1200	1400	2300	Shift 2	Shift 1
6-Jun	300	1200	1400	2300	Shift 2	Shift 1
7-Jun	300	1200	1400	2300	Shift 2	Shift 1
8-Jun	300	1200	1400	2300	Shift 2	Shift 1
9-Jun	300	1200	1400	2300	Shift 2	Shift 1
10-Jun	300	1200	1400	2300	Shift 2	Shift 1
11-Jun	300	1200	1400	2300	Shift 2	Shift 1
12-Jun	300	1200	1400	2300	Shift 2	Shift 1
13-Jun	300	1200	1400	2300	Shift 2	Shift 1
14-Jun	300	1200	1400	2300	Shift 2	Shift 1
15-Jun	300	1200	1400	2300	Shift 2	Shift 1
16-Jun	300	1200	1400	2300	Shift 2	Shift 1
17-Jun	300	1200	1400	2300	Shift 2	Shift 1
18-Jun	300	1200	1400	2300	Shift 2	Shift 1
19-Jun	300	1200	1400	2300	Shift 1	Shift 2
20-Jun	300	1200	1400	2300	Shift 1	Shift 2
21-Jun	300	1200	1400	2300	Shift 1	Shift 2
22-Jun	300	1200	1400	2300	Shift 1	Shift 2
23-Jun	300	1200	1400	2300	Shift 1	Shift 2
24-Jun	300	1200	1400	2300	Shift 1	Shift 2
25-Jun	300	1200	1400	2300	Shift 1	Shift 2
26-Jun	300	1200	1400	2300	Shift 1	Shift 2
27-Jun	300	1200	1400	2300	Shift 1	Shift 2
28-Jun	300	1200	1400	2300	Shift 1	Shift 2
29-Jun	300	1200	1400	2300	Shift 1	Shift 2
30-Jun	300	1200	1400	2300	Shift 1	Shift 2

Continued

Appendix A2.–Page 2 of 3.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
1-Jul	300	1200	1400	2300	Shift 1	Shift 2
2-Jul	300	1200	1400	2300	Shift 1	Shift 2
3-Jul	300	1200	1400	2300	Shift 2	Shift 1
4-Jul	300	1200	1400	2300	Shift 2	Shift 1
5-Jul	300	1200	1400	2300	Shift 2	Shift 1
6-Jul	300	1200	1400	2300	Shift 2	Shift 1
7-Jul	300	1200	1400	2300	Shift 2	Shift 1
8-Jul	300	1200	1400	2300	Shift 2	Shift 1
9-Jul	300	1200	1400	2300	Shift 2	Shift 1
10-Jul	300	1200	1400	2300	Shift 2	Shift 1
11-Jul	300	1200	1400	2300	Shift 2	Shift 1
12-Jul	300	1200	1400	2300	Shift 2	Shift 1
13-Jul	300	1200	1400	2300	Shift 2	Shift 1
14-Jul	300	1200	1400	2300	Shift 2	Shift 1
15-Jul	300	1200	1400	2300	Shift 2	Shift 1
16-Jul	300	1200	1400	2300	Shift 2	Shift 1
17-Jul	300	1200	1400	2300	Shift 1	Shift 2
18-Jul	300	1200	1400	2300	Shift 1	Shift 2
19-Jul	300	1200	1400	2300	Shift 1	Shift 2
20-Jul	300	1200	1400	2300	Shift 1	Shift 2
21-Jul	300	1200	1400	2300	Shift 1	Shift 2
22-Jul	300	1200	1400	2300	Shift 1	Shift 2
23-Jul	300	1200	1400	2300	Shift 1	Shift 2
24-Jul	300	1200	1400	2300	Shift 1	Shift 2
25-Jul	300	1200	1400	2300	Shift 1	Shift 2
26-Jul	300	1200	1400	2300	Shift 1	Shift 2
27-Jul	300	1200	1400	2300	Shift 1	Shift 2
28-Jul	300	1200	1400	2300	Shift 1	Shift 2
29-Jul	300	1200	1400	2300	Shift 1	Shift 2
30-Jul	300	1200	1400	2300	Shift 1	Shift 2

Continued

Appendix A2.–Page 3 of 3.

	Shift 1		Shift 2		Crew Schedule	
	start	stop	Start	Stop	Crew 1	Crew 2
1-Aug	300	1200	1400	2300	Shift 2	Shift 1
2-Aug	300	1200	1400	2300	Shift 2	Shift 1
3-Aug	300	1200	1400	2300	Shift 2	Shift 1
4-Aug	300	1200	1400	2300	Shift 2	Shift 1
5-Aug	300	1200	1400	2300	Shift 2	Shift 1
6-Aug	300	1200	1400	2300	Shift 2	Shift 1
7-Aug	300	1200	1400	2300	Shift 2	Shift 1
8-Aug	300	1200	1400	2300	Shift 2	Shift 1
9-Aug	300	1200	1400	2300	Shift 2	Shift 1
10-Aug	300	1200	1400	2300	Shift 2	Shift 1
11-Aug	300	1200	1400	2300	Shift 2	Shift 1
12-Aug	300	1200	1400	2300	Shift 2	Shift 1
13-Aug	300	1200	1400	2300	Shift 2	Shift 1
14-Aug	300	1200	1400	2300	Shift 2	Shift 1
15-Aug	300	1200	1400	2300	Shift 1	Shift 2
16-Aug	300	1200	1400	2300	Shift 1	Shift 2
17-Aug	300	1200	1400	2300	Shift 1	Shift 2
18-Aug	300	1200	1400	2300	Shift 1	Shift 2
19-Aug	300	1200	1400	2300	Shift 1	Shift 2
20-Aug	300	1200	1400	2300	Shift 1	Shift 2
21-Aug	300	1200	1400	2300	Shift 1	Shift 2
22-Aug	300	1200	1400	2300	Shift 1	Shift 2
23-Aug	300	1200	1400	2300	Shift 1	Shift 2
24-Aug	300	1200	1400	2300	Shift 1	Shift 2
25-Aug	300	1200	1400	2300	Shift 1	Shift 2
26-Aug	300	1200	1400	2300	Shift 1	Shift 2
27-Aug	300	1200	1400	2300	Shift 1	Shift 2
28-Aug	300	1200	1400	2300	Shift 1	Shift 2

Appendix A3.–Radio tag deployment log.

TAG DEPLOYMENT LOG 2014

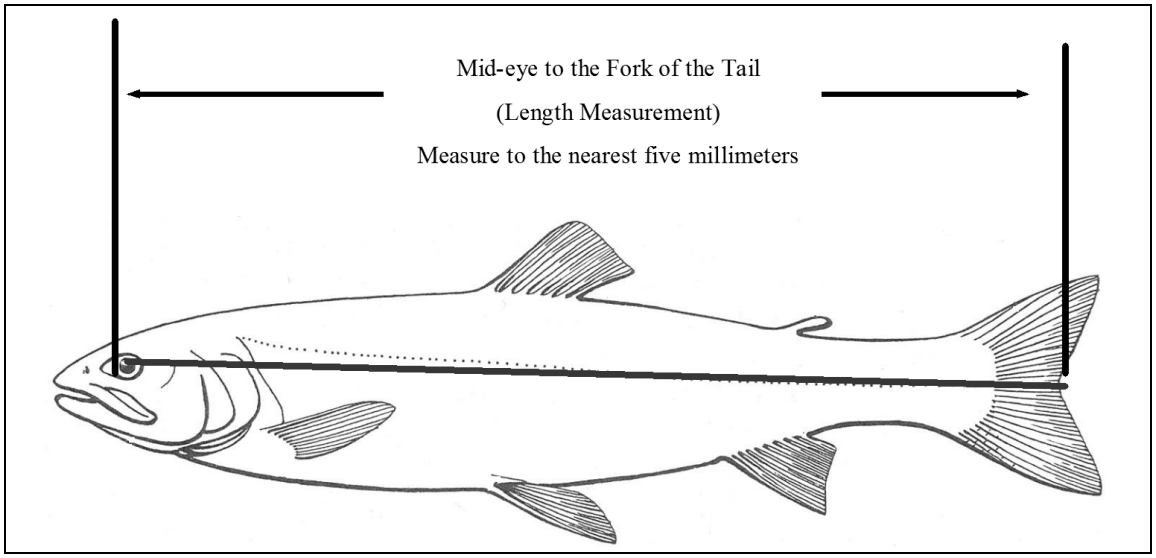
Date:____________________ Recorder:____________________ Shift: 1 2

Tagging Site: Yentna Mainstem FW GN

Tags Deployed		Tags to be dployed by next crew	
Tag Number	Location	Tag Number	Location
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN
____________	FW1 FW2 GN	____________	FW1 FW2 GN

Comments:

APPENDIX B: SAMPLING PROCEDURES FOR LENGTH AND TISSUE



Appendix B1.–Measuring salmon for length (mid eye to tail fork).

Appendix B2.–Genetic tissue sample collection procedures.

Non-lethal Sampling of Finfish Tissue for DNA Analysis

ADF&G Gene Conservation Lab, Anchorage

I. General Information

We use axillary process samples from individual fish to determine the genetic characteristics and profile of a particular run or stock of fish. This is a non-lethal method of collecting tissue samples from adult fish for genetic analysis. The most important thing to remember in collecting samples is that **only quality tissue samples give quality results**. If sampling from carcasses: tissues need to be as "fresh" and as cold as possible and recently moribund, do not sample from fungal fins.

Sample preservative: Ethanol (ETOH) preserves tissues for later DNA extraction without having to store frozen tissues. Avoid extended contact with skin.

II. Sample procedure:

1. Tissue type: Axillary process, clip axillary process from each fish (Appendix B3).
2. Data to record: Record each vial number to paired data information.
3. Prior to sampling, fill the tubes half way with ETOH from the squirt bottle. Fill only the tubes that you will use for a particular sampling period.
4. To avoid any excess water or fish slime in the vial, wipe the axillary process dry prior to sampling. Using the dog toe nail clipper or scissors, clip off axillary process (**1/2 -1" max**) to fit into the cryovial.
5. Place axillary process into ETOH. The tissue/ethanol ratio should be **slightly less than 1:3** to thoroughly soak the tissue in the buffer.
6. Top up tubes with ETOH and screw cap on securely. Invert tube twice to mix ETOH and tissue. Periodically, wipe the dog toe nail clippers or scissor blade so not to cross contaminate samples.
7. Discard remaining ethanol from the 500ml bottle before returning samples. **Tissue samples must remain in 2ml ethanol** after sampling. HAZ-MAT paperwork will be required for return shipment. Store vials containing tissues at cool or room temperature, away from heat in the white sample boxes provided. In the field: keep samples out of direct sun, rain and store capped vials in a dry, cool location. Freezing not required.

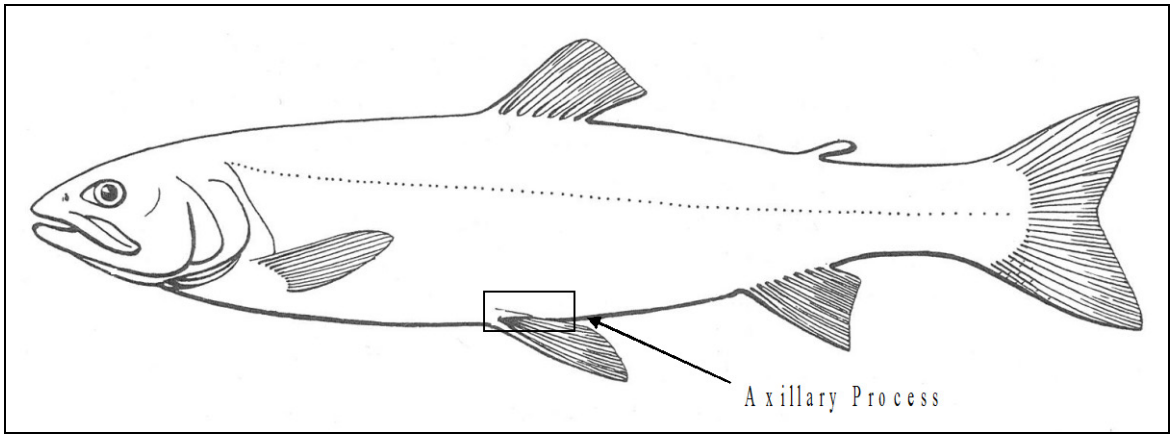
III. Supplies included with sampling kit:

1. (1) – Dog toe nail clipper - used for cutting the axillary process
2. (1) – Scissors can be used to cut a portion axillary process – if clippers don't work for your crew
3. Cryovial- a small (2ml) plastic vial, pre-labeled.
4. Caps – with or without gasket to prevent evaporation of ETOH.
5. Cryovial rack- white plastic rack with holes for holding cryovials while sampling
6. Ethanol (ETOH) – in (2) 500 ml plus (1) – 125 ml Nalgene bottle
7. Squirt bottle – to fill or "top off" each cryovial with ETOH
8. Paper towels – use to blot any excess water or fish slime off axillary process
9. Printout of sampling instructions
10. (3) – three pair of lab gloves (size large)
11. Laminated "return address" label

IV. Shipping: HAZMAT paperwork is required for return shipment of these samples and is included in the kit.

Ship samples to: ADF&G – Genetics
333 Raspberry Road

Lab staff: 1-907-267-2247
Judy Berger: 1-907-267-2175



Appendix B3.–Location of axillary process.

APPENDIX C: CATCH AND EFFORT DATA FORMS

Appendix C1.–Catch and effort data form for mainstem Susitna River, 2014.

MAINSTEM SUSITNA - FISHWHEEL CATCH AND EFFORT CHINOOK, COHO & PINK- 2014

Date:		Shift: 1 2		Samplers:		Fishwheel: 1 2					
Spin Time											
Start:	**Stop:**	**Start:**		**Stop:**		**Start:**	**Stop:**	**Start:**	**Stop:**	**Total Min.**	
FW Checks		**Chinook**		**Coho**		**Pink**					
Start	Stop	**Tags**	**Untagged**	**Tags**	**Untagged**	**Tags**	**Untagged**	Sockeye	Chum	Non salmon*	**Notes**
	Totals										

*NP=Northern Pike, B=Burbot, AG=Arctic Grayling, RT=Rainbow Trout, BC=Bering Cisco, HWF=Humpback Whitefish, RWF=Round Whitefish, LNS=Longnose Sucker, AC=Arctic Char

-continued-

Radio Tags

Species	Frequency	Code	Vial	MEF Length	Total Length	Release Time	Notes

Appendix C2.–Catch and effort data form for mainstem Susitna River gillnet, 2014.

MAINSTEM SUSITNA - CHINOOK GILL NET - CATCH AND EFFORT/RADIO TAG FORM - 2014

Location: Date: Sampler names: Shift: 1 2

						Other Salmon					
Set	**Mesh**	**Start**	**End**	**# Radios**	**Total**	**Sockeye**	**Coho**	**Pink**	**Non - salmon***	**# Rel/Esc**	**Comments**
Totals											

*NP=Northern Pike, B=Burbot, AG=Arctic Grayling, RT=Rainbow Trout, BC=Bering Cisco, HWF=Humpback Whitefish, RWF=Round Whitefish, LNS=Longnose Sucker, AC=Arctic Char/Dolly

-continued-

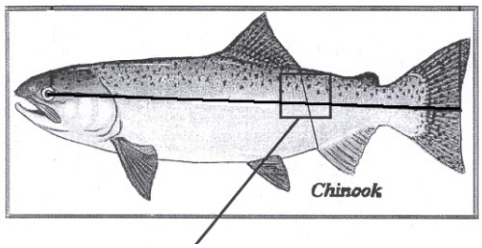
RADIO TAGGING SUMMARY - GILL NET CATCH

Radio Freq.	Pulse	MEF Length	Total Length	Comments

APPENDIX D: SCALE COLLECTION PROCEDURE

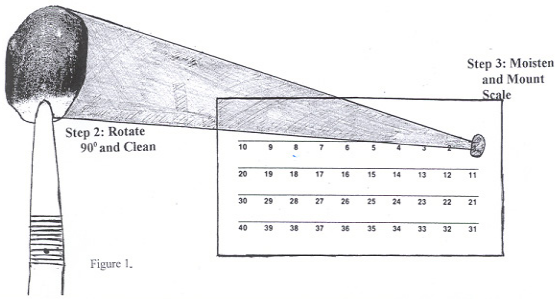
Appendix D1.–Scale collection procedure.

A "preferred scale" is located on the left side of the fish, 2 rows above the lateral line along a diagonal line from the back (posterior) of the dorsal fin to the front **(anterior**) of the anal fin.



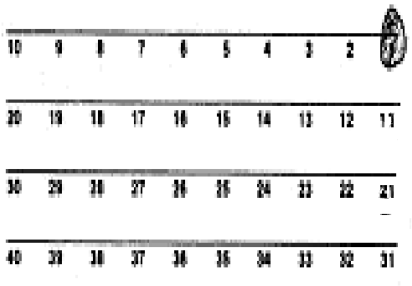
Pluck the preferred scale from the fish using forceps. Pliers may be necessary to remove scales if the fish has been in freshwater for an extended period, as happens during late season sampling.

Remove all slime, grit, and skin from the scale by moistening and rubbing between thumb and forefinger. Moisten the clean scale and mount it on the gummed card directly on top of the number "1".



A good scale has a well-rounded shape. Hold the scale up to light and examine for overall size, shape, regeneration, deformities, etc.

Continuing, mount the second and third scales from fish number 1 onto the numerals "11" and "21", filling in each column. Only 10 fish will fit on a card, 1 fish per column.



APPENDIX E: SIZE SELECTIVE SAMPLING AND CONTINGENCY TESTS

Appendix E1.–Detection of size and/or sex selective sampling during a 2-sample mark–recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov 2-sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first 2 tests when sample sizes are small. Guidelines for small sample sizes are less than 30 for R and less than 100 for M or C.

Sex selective sampling: Contingency table analysis (χ^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M and R, C and R, and M and C using the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. If the proportions by gender are estimated for a sample (usually C), rather than observed for all fish in the sample, contingency table analysis is not appropriate, and the proportions of females (or males) are then compared between samples using a 2-sample test (e.g. Student's *t*-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o
There is no size/sex selectivity detected during either sampling event.		
Case II:		
Reject H_o	Fail to reject H_o	Reject H_o
There is no size/sex selectivity detected during the first event but there is during the second event sampling.		
Case III:		
Fail to reject H_o	Reject H_o	Reject H_o
There is no size/sex selectivity detected during the second event but there is during the first event sampling.		
Case IV:		
Reject H_o	Reject H_o	Either result possible
There is size/sex selectivity detected during both the first and second sampling events.		
Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences, which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R *P*-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event, which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

-continued-

C. If a) sample sizes for C vs. R are small, b) the C vs. R *P*-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event, which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R *P*-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events, which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2} \sum_{i=1}^{j} \left(\hat{N}_i^2 \hat{V}\left[\hat{p}_{ik}\right] + \left(\hat{p}_{ik} - \hat{p}_k\right)^2 \hat{V}\left[\hat{N}_i\right] \right). \tag{2}$$

where:
j = the number of sex/size strata;
$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;
$\hat{N}_i$ = the estimated abundance in stratum i; and,
$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least 1 must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these 3 assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least 1 null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all 3 tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.–Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not Recaptured
	1	**2**	**…**	***t***	(n_1-m_2)
1					
2					
…					
s					

II.–Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	***t***
Marked (m_2)				
Unmarked (n_2-m_2)				

III.–Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	**2**	**…**	***s***
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

Appendix E3.–Tables describing anticipated sampling rates and sample sizes.

Table E3-1.–Anticipated sampling rates and sample sizes necessary to estimate abundance within ±25%, 90% of the time using a Darroch model (or ±12.5% using a Petersen model) and adjusting for 20% loss of marked fish.

				2nd Event	
Population size (N)	Marks deployed	Mark loss	Valid marks	Sample size needed	Sample % of N
120,000	700	20%	560	28,495	23.75%
100,000	700	20%	560	23,729	23.73%
80,000	700	20%	560	18,963	23.70%
60,000	700	20%	560	14,197	23.66%
40,000	700	20%	560	9,431	23.58%

Table E3-2.–Anticipated sampling rates and sample sizes necessary to estimate abundance within ±40%, 90% of the time using a Darroch model (or ±20% using a Petersen model) and adjusting for 30% loss of marked fish.

				2nd Event	
Population size (N)	Marks deployed	Mark loss	Valid marks	Sample size needed	Sample % of N
120,000	600	30%	420	17,075	14.23%
100,000	600	30%	420	14,221	14.22%
80,000	600	30%	420	11,366	14.21%
60,000	600	30%	420	8,512	14.19%
40,000	600	30%	420	5,657	14.14%

-continued-

Table E3-3.–Anticipated sampling rates and sample sizes necessary to estimate abundance within ±40%, 90% of the time using a Darroch model (or ±20% using a Petersen model) and adjusting for 15% loss of marked fish.

Population size (N)	Marks deployed	Mark loss	Valid marks	2nd Event sample size needed
70,000	1,000	15%	850	5,261
70,000	1,500	15%	1,275	3,576
70,000	2,000	15%	1,700	2,701
70,000	2,320	15%	1,972	2,332
70,000	2,500	15%	2,125	2,164
60,000	1,000	15%	850	4,501
60,000	1,500	15%	1,275	3.056
60,000	2,000	15%	1,700	2,306
60,000	2,140	15%	1,819	2,156
60,000	2,500	15%	2,125	1,846
50,000	1,000	15%	850	3,741
50,000	1,500	15%	1,275	2,537
50,000	1,960	15%	1,666	1,950
50,000	2,000	15%	1,700	1,911
50,000	2,500	15%	2,125	1,527
40,000	1,000	15%	850	2,981
40,000	1,500	15%	1,275	2,017
40,000	1,740	15%	1,479	1,742
40,000	2,000	15%	1,700	1,516
40,000	2,500	15%	2,125	1,209

-continued-

Table E3-4.–Anticipated sampling rates and sample sizes necessary to estimate abundance within ±40%, 90% of the time using a Darroch model (or ±20% using a Petersen model) and adjusting for 30% loss of marked fish.

Population size (N)	Marks deployed	Mark loss	Valid marks	2nd Event sample size needed
120,000	2,000	30%	1,400	5,645
120,000	3,000	30%	2,100	3,801
120,000	3,380	30%	2,366	3,379
120,000	4,000	30%	2,800	2,857
120,000	5,000	30%	3,500	2,283
120,000	6,000	30%	4,200	1,897
100,000	2,000	30%	1,400	4,693
100,000	3,000	30%	2,100	3.157
100,000	3,080	30%	2,156	3,076
100,000	4,000	30%	2,800	2,370
100,000	5,000	30%	3,500	1,891
100,000	6,000	30%	4,200	1,570
80,000	2,000	30%	1,400	3,742
80,000	2,740	30%	1,918	2,749
80,000	3,000	30%	2,100	2,512
80,000	4,000	30%	2,800	1,882
80,000	5,000	30%	3,500	1,500
80,000	6,000	30%	4,200	1,242

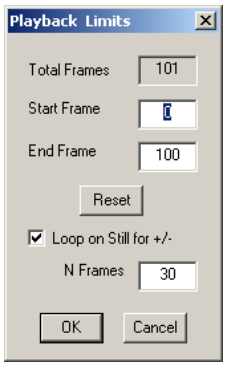
APPENDIX F: INSTRUCTIONS FOR ECHOGRAM MEASUREMENTS

Appendix F1.–Instructions and settings for manual length measurements using Sound Metrics Software Version 5.25.11 (or higher if a version with bug-fixes or needed features is subsequently released).

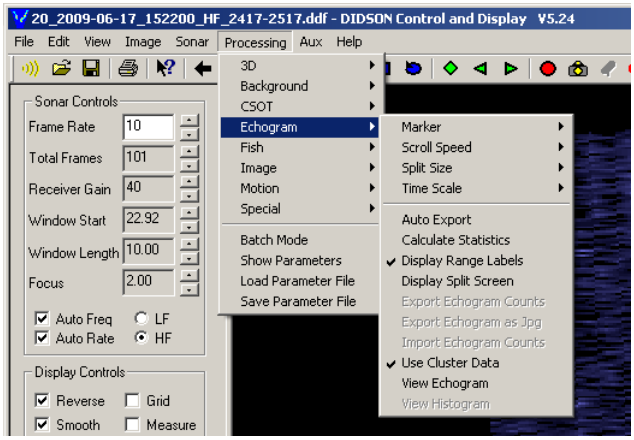
Parameter setup prior to beginning measurements:

Step 1. set the number of frames displayed (i.e., when right-clicking on a fish in echogram mode to display in movie mode) from the default of plus minus one second to +- any number of frames:

1. Select **<image><playback><set endpoints>**
2. [√] Loop on still for +/- N frames
3. Enter the number of frames (I suggest 20-30) but you be the judge



Step 2. Select **<Processing><Echogram><Use Cluster Data>** if you want to use ALL the beams when creating your Echogram (we generally do). You can use fewer beams by unchecking this option and going to the

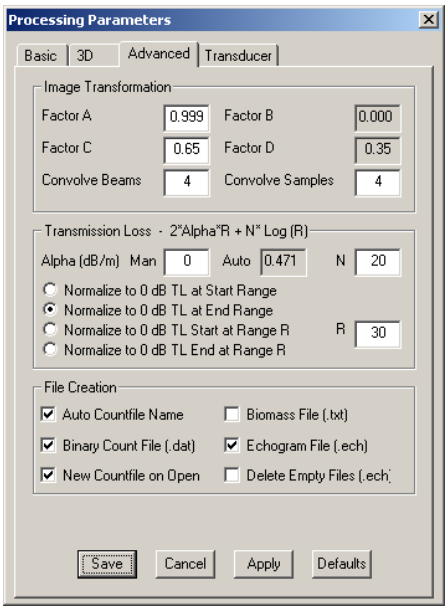


Step 3. Set up your **processing parameters** (last Icon on right) for **File Creation** as follows:

- ✓ Auto Countfile Name
- ✓ Binary Count File (.dat)
- ✓ New Countfile on Open
- ✓ Echogram File (.ech)

! DO NOT check Biomass file or Delete Empty Files

-continued-



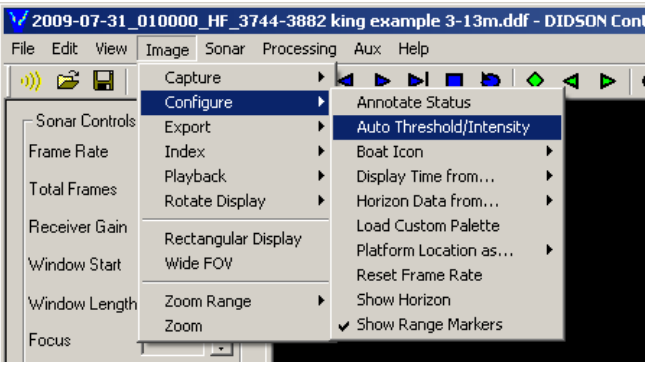
Step 4. You can reload your Echogram counts to finish at a later time if you have checked the Echogram file as follows:

1. Select **<File><Open> then Files of type .ech** from drop-down menu
2. Open desired file
3. The Echogram should reload showing you your previous measurements

Or this option will work as long as you saved the .dat file (as shown above)

1. Open the file and bring up your echogram as usual (follow instructions below)
2. Select **<Processing><Echogram><Import Echogram Counts>**
3. Select the **.dat** file with your saved counts – file should reload showing you your previous measurements (the filename for the .dat file will begin with **FC_**)

Step 5. Make sure <Image><Configure><Auto Threshold/Intensity> is UNCHECKED! This will keep your threshold and intensity settings from changing when you switch between echogram and movie mode



Step 6. Uncheck the 'Display Raw Data' toolbar icon (first button on left in Combined toolbar). (If you are in the movie mode and it is displaying the raw image data, it is because 'Display Raw Data' is enabled by default).

-continued-

Caveats/Tips:

- ✓ Don't forget to ***save your work frequently*** by selecting the [e] key – the first time you do this in each file, it will ask for your initials
- ✓ Try not to use more than 4-5 segments to outline the fish (this may artificially increase the length of the fish) – starting at the snout and following the mid-section of the fish to the tip of the tail
- ✓ Uncheck **<View> <Header>** (or use icon) to increase size of echogram or image

Instructions for manual echogram-based length measurements

***note that these settings may already be active as some of them have "memory" and are saved until changed**

1. Select **<BS>** (for background subtraction) from toolbar - or under **<Processing><Background><Background Subtraction>**
2. Select **<Processing><Background><Fixed Background>**
3. Select threshold and range settings given in Table F1-1 (To adjust these settings, use the slider bars under Display Controls to the left of the echogram).
4. Select **<EG>** (for view Echogram) from toolbar or under **<Processing><Echogram><View echogram**>
5. **<left mouse click>** on the echogram near\on the fish trace of interest to "mark it" - you should see a white circle
6. **<right mouse click>** INSIDE the white circle to switch to movie mode (movie mode will play the 16 frames encompassing this circle continuously)
7. Press **<space bar>** to pause movie
8. Step through the movie frames using the right or left arrows until you find a frame that you think displays the entire length of the fish well (see section below on selecting optimal images).
9. **<right mouse click drag>** will magnify the area in the rectangle
10. **<left mouse click>** on the FISH SNOUT and continue to <left click> along the body to create a "segmented measurement." ***The segments should follow the midline of the body of the fish*** – ending with the tail. Try not to use more than three or four segments to define the fish (Figures F1–F2,)
11. **<double left mouse click>** or select **<f>** key to add measurement to file (fish it!)
12. **<right mouse click>** to unzoom
13. **<right mouse click>** to return to Echogram

Hot keys:

1. **<e>** to "save" your echogram measurements to file
2. **<f>** to "fish it" (enter it in the text file of measured fish)
3. **<u>** to "undo" the last segment
4. **<d>** to "delete" the all segments
5. **<space bar>** to pause in movie mode (if this doesn't work – click in the black area of the display)
6. **<right arrow>** forward direction when you select play or advances frame one at a time if the pause button is on (pause button = blue square on the toolbar)
7. **<left arrow>** opposite of above
8. **Left Mouse Click Drag –** to show movie of the selected fish
9. **Right Mouse Click Drag –** zooms the selected area

-continued-

Table F1-1.–Threshold and intensity settings for range strata. To adjust these settings, use slider bars under the Display Controls to the left side of the Echogram or Movie window.

	3.3-8.3m	**8.3-13.3m**	**13.3-23.3m**	**23.3-33.3m**
Threshold	11	11	10	9
Intensity	50	50	45	40

Selecting optimal images to measure

Measurements should be taken from frames where contrast between the fish image and background are high and where the fish displays its full length (e.g. Panels a, d, and f in Figure E1-1). In general, the best images are obtained when the fish is sinusoidal in shape (rather than straight and perfectly perpendicular) because the head and tail appear most visible when there is curvature to the fish body (e.g. Figures F1–F2). Figures F1–F2 demonstrate the process of measuring a fish using the manual measuring tool. The user pauses the DIDSON movie (top), zooms in on the fish of interest (middle), and measures the fish length with a segmented line created by mouse clicks along the center axis of the fish (bottom). The first mouse click is made at the leading edge of the pixel associated with the snout and the final click on the trailing edge of the pixel associated with the tail. The software adds the individual segment lengths that are calculated from the pixel coordinates of the DIDSON image.

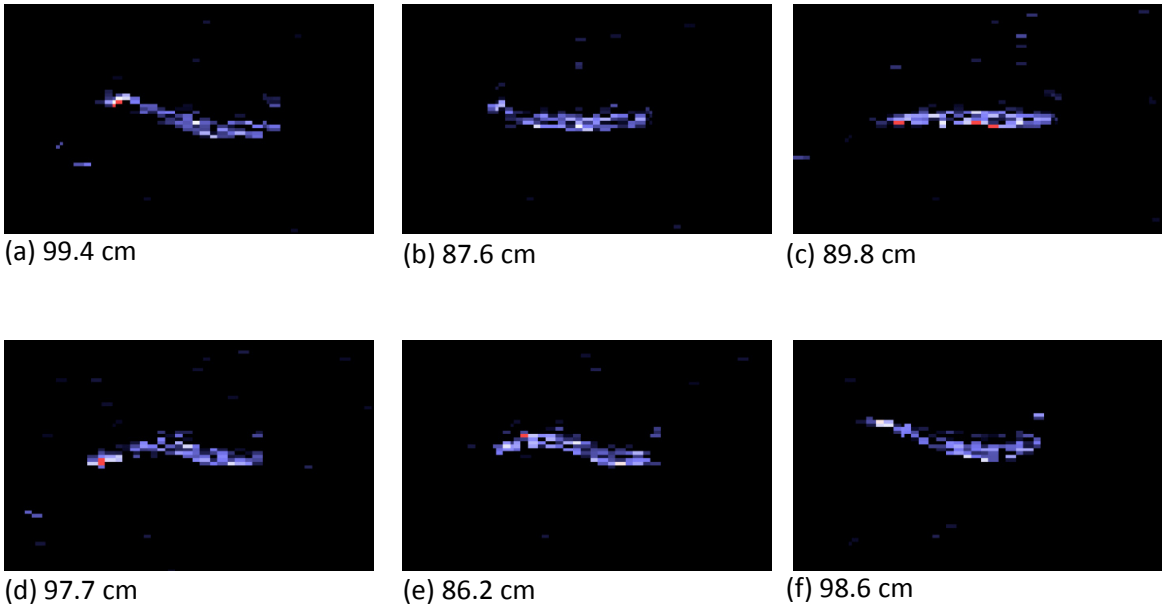


Figure E1-1.–Panels a-f show the variability in length measurements from DIDSON images of a tethered Chinook salmon during one full tail-beat cycle (adapted from Burwen et al. 2010).

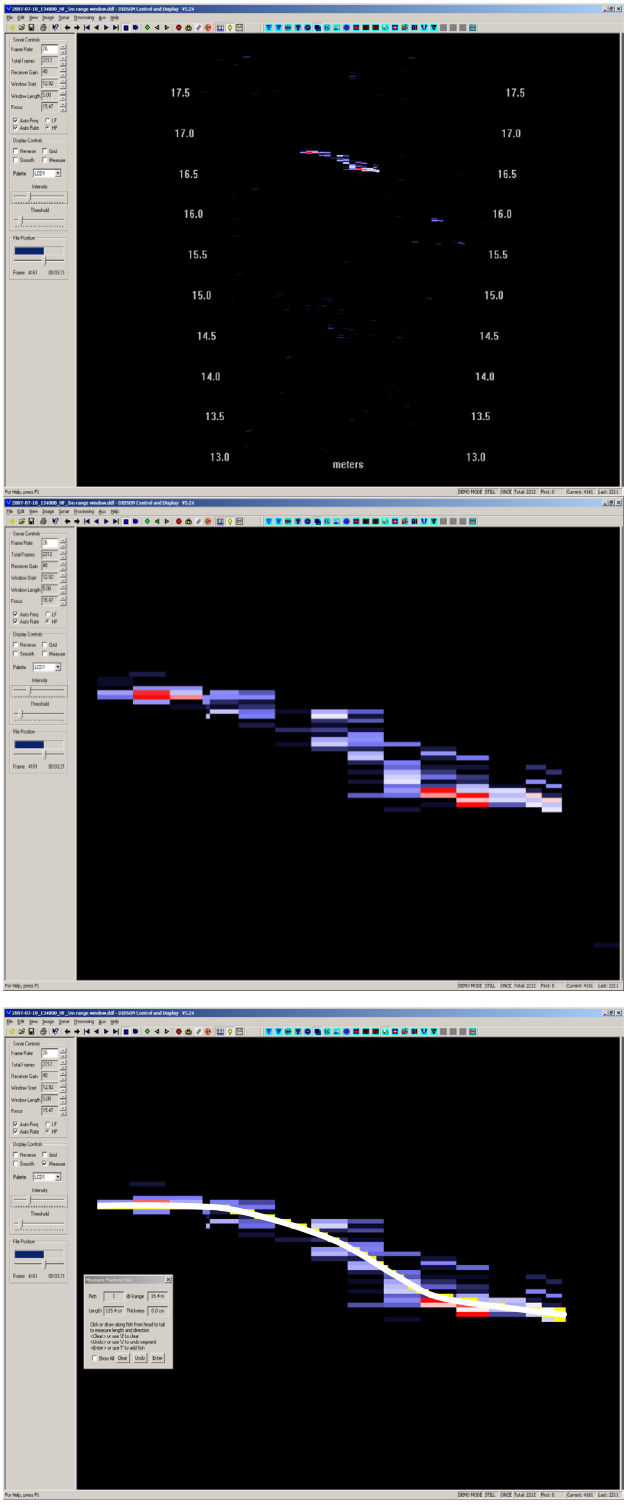


Figure F1-2.–DIDSON images from a tethered Chinook salmon showing the original DIDSON image (top), the zoomed image (middle), and the segmented lines that result when the observer clicks along the length of the fish to mark its length (bottom). Adapted from Burwen et al. 2010.

APPENDIX G: ASSESSING ACCURACY OF ARIS IMAGE ANALYSIS MEASUREMENTS

Appendix G1.–Assessing the accuracy of ARIS image analysis measurements of Chinook salmon.

During 2014, data will be collected at the Deshka River weir for estimating the relationships between known standard salmon length measurements and estimates of length from ARIS images.

A DIDSON sonar will deployed immediately upstream of the Deshka River weir prior to or as soon as possible after the beginning of Chinook salmon passage, dependent on water conditions. After deployment of the sonar, inner and outer boundaries of the 3 insonification zones will be identified and marked on the upstream side of the weir.

Initially, Chinook salmon will be sampled for ASL according to the schedule described in the 2014 Deshka River weir operational plan (citation?) with the following additional data collected. Each Chinook salmon will be measured for METF length, snout to fork of tail (FL), and snout to a line extending between the posterior tips to the caudal lobes (TL).

After necessary ASL data are collected for each sampled Chinook salmon and prior to release, technicians will identify which insonification zone is active for the sonar above the weir. The sampled Chinook salmon will then be gently released above the weir near the center of the active insonification zone. Time of release, coordinated with the time counter for the sonar will be recorded.

ARIS images from the sonar will be reviewed concurrently with release of fish or immediately after the completion of ASL sampling. Adjustments to the procedure described above will be made on site, as necessary, to ensure the capture of ARIS images of known length Chinook salmon.

The desired sampling intensity across the size range of Chinook salmon is at least 3 Chinook salmon from each of the following size ranges released into each of the 3 insonification zones when the zones are active:

400–449 mm METF,

500–549 mm METF,

550–599 mm METF,

600–649 mm METF,

650–699 mm METF,

700–749 mm METF,

750–799 mm METF,

800–849 mm METF,

850–899 mm METF,

900–949 mm METF,

950–999 mm METF, and

1000+ mm METF.

Minimum samples size is at least 1 Chinook salmon from each of the above size ranges released into each of the 3 insonification zones when the zones are active.

For each of the known lengths (METF, FL, TL), a simple linear regression will be conducted to estimate the parameters for the relationship between ARIS length (dependent variable) and known length (independent variable). The regression will be fitted with ARIS length as the dependent variable because significant measurement error is expected to be present in the ARIS length estimates and the measurement error in the known length measurements can be assumed to be relatively small. After fitting these relationships, inverse regression methods will be used to construct equations to predict the known lengths from ARIS lengths (Neter et al, 1985).